AN ABSTRACT OF THE THESIS OF

Stephanie Lee Madson for the degree of Master of Science in Entomology presented on December 8, 1997. Title: Correlation between Structural Heterogeneity and Arthropod Biodiversity: Implications for Management of Pacific Northwest Forests.

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Abstract approved: _____

Andrew R. Moldenke

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Robert P. Griffiths

The "old-growth controversy" in the Pacific Northwest recognized thinning as the primary silvicultural practice for land managers to produce wildlife habitat while continuing to produce timber. For the foreseeable future, forest stands will be harvested to produce forest gaps and a patchwork of trees of different ages. In order to evaluate the effect of thinning on biodiversity, nine 15-year-old harvests of this type (age=70 years) were paired with adjacent old-growth and even-aged, unthinned "pole" stands.

Since soil is the crucible of terrestrial biodiversity, it is critical to contrast the effects upon the forest floor of this future practice with current management. Soil and litter fauna were monitored along 250 meter transects (pitfall and Berlese sampling at ten-meter intervals) to meet the following objectives: 1) to determine biological diversity on public lands, per federal mandate, and use diversity as a management tool; 2) compare

levels of biodiversity between three management strategies; 3) determine best methods to assay arthropod diversity; and 4) identify structural and environmental determinants of arthropod diversity and abundance. The study's hypotheses were: 1) old-growth forests will have greater arthropod diversity than thinned stands; 2) thinned stands will have greater arthropod diversity than unthinned stands; and 3) species found within old-growth stands, but not within unthinned pole stands, will also be found in thinned stands.

This study contrasted nine Western Hemlock/Douglas-fir sites each with contrasting old-growth, thinned and unthinned pole management stands. Sites were equally blocked in Southern Oregon, the Coast Range, and the Cascade Mountains. No segment of the arthropod fauna (i.e., pitfall-trapped epigeic macroarthropods, Berlese-extracted litter-dwelling meso- and microarthropods, or soil-dwelling microarthropods) exhibited a management (treatment) effect throughout the entire region. When the regional blocking was removed, within-region analysis generally revealed that old-growth was most distinct. Old-growth stands had the highest abundance of individuals, but were comprised of the fewest species. Thinned stands were characterized by the highest species richness. Within-region analysis revealed an interaction of management effects and specific locale effects; locale effects dominated for soil microarthropods and epigeic macroarthropods, while management options dominated for litter arthropods.

Within the Southern Oregon region, I attempted to correlate arthropod community structure (canonical correspondence analysis (CCA) of within-stand samples) with a suite of soil chemical and microbiological descriptors. Full analysis of twelve variables within one exemplary stand revealed several potential trends (negative: dissolved organic carbon,

soil moisture, distance from the beginning of the transect; positive: total CO_2 field respiration, mineralizable nitrogen, water-induced respiration, substrate-induced respiration). Relatively shallow slopes and very low r-value coefficients of correlation characterized all statistical tests. Few of the trends apparent at one site were paralleled at more than one other site; at all sites potential correlates had very low r-values. No community revealed separate clouds in CCA analysis, indicating distinct "micro-communities" of arthropods inhabiting distinct micro-habitats. Lack of distinctive species assemblages and lack of correlation with microhabitat variables indicated that arthropods respond on different temporal and/or spatial scales then the microbial-oriented variables, and that each taxon is responding in an individual manner.

Correlation between Structural Heterogeneity and Arthropod Biodiversity: Implications for Management of Pacific Northwest Forests.

by

Stephanie Lee Madson

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APPROVED:

Redacted for Privacy

Co-major Professor, representing Entomology

Redacted for Privacy

Co-major Professor, representing Entomology

Redacted for Privacy

Chair of Department of Entomology

Redacted for Privacy

Dean of Graduate School

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Stephanie Lee Madson, Author

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CONTRIBUTION OF AUTHORS

Drs. Andrew Moldenke and Robert Griffiths, my co-major professors, were involved in the design, data collection, sample identification and writing of both manuscripts.

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Introduction

Timber production and recreation historically have been two of the dominant management goals for forested public lands in the Pacific Northwest. Large-scale modification of the landscape, primarily in the form of logging and associated activities, has endangered species, especially those that favor old-growth characteristics, such as multi-storied canopies and diverse structure. During the last decade, management goals for forested public lands have shifted to encompass the need to maintain ecosystem processes, species diversity, and habitat structure of forested lands, while continuing timber production (Franklin 1993, McComb *et al.* 1993, Hopwood 1991, Caza 1993). Public agencies are now actively seeking management strategies for monitoring and maintaining species diversity, while allowing timber production to continue on public lands.

Thinning is the silvicultural practice of reducing stand density through the partial removal of the overstory canopy (Bailey 1996, Tappeiner 1992). This practice has been recognized as the primary tool for land managers to meet the specific objective of producing habitat with old-growth characteristics across thousands of acres of young and middle-aged timber (Tappeiner 1992, FEMAT 1993, Record of Decision 1994, Cole 1996). Thinning also releases the remaining trees from crowded stands, allowing the trees to grow larger and healthier.

Arthropods are integral to a functioning forest ecosystem and perform key roles as detritivores, herbivores, predators and prey. Soil and litter arthropods aid in the regulation of rates of nutrient cycling, decomposition and energy flow (Wardle and Giller 1996, Seastedt 1984, Moldenke *et al.* 1994, Christiansen *et al.* 1989). It has been demonstrated in several field studies that biological diversity is beneficial for ecosystem functioning and sustainability (Kareiva 1996, Tilman *et al.* 1996, Tilman and Downing 1994, Vitousek and Hooper 1993, McNaughton 1993, Wilson 1992, Chapin *et al.* 1995). Few studies, if any, have shown what determines arthropod diversity in Pacific Northwest forests, especially in belowground systems.

The first chapter addresses the question of how the management practice of thinning alters the biological diversity and community composition of soil and litter arthropods compared to past management strategies (unthinned (pole) and old-growth stands). The second chapter correlates microhabitat variables and forest structure within Pacific Northwest forests with soil arthropod community composition, in an effort to identify the determinants of arthropod diversity within stands. In conclusion, implications of the findings of these studies are discussed in relation to forest management strategies in the Pacific Northwest.

Chapter 2

Effects of Stand Management upon Arthropod Community Composition and Diversity in Douglas-fir Stands in Western Oregon.

Stephanie L. Madson

Introduction

For many years, timber production and recreation were the dominant management goals for forested public lands in the Pacific Northwest. During the last decade, management goals for forested public lands now address ecosystem processes, species diversity, and habitat on forested lands (Franklin 1993, McComb *et al.* 1993, Hopwood 1991, Caza 1993). Historical records estimate that 100 years ago, 60 to 70 percent of the forested areas west of the Cascade crest in Oregon, Washington and Northern California was late-successional, "old-growth" forests (Norse 1990). Today, old-growth forests occupy only 20 percent of that area. Traditional harvesting practices have been clearcutting, followed by planting of Douglas-fir seedlings and early control of hardwoods and shrubs (Scott 1980). Harvest typically follows 60 to 100 years after planting (Bailey 1996). This large-scale modification of the landscape has endangered species that favor old-growth characteristics, such as multi-storied canopies and diverse structure, and has increased the vulnerability of the remaining forest ecosystems to natural stresses such as fire, wind, pathogens and weeds (Perry 1988, Agee 1993). Therefore, at a regional scale, in order to maintain ecosystem processes and provide habitat structure while continuing to produce timber, it will be necessary to create a dynamic mosaic of stands across the landscape by utilizing several contrasting management strategies, including restoration of old-growth characteristics (Tappeiner 1992).

Thinning is the silvicultural practice of reducing stand density through partial removal of the overstory canopy (Bailey 1996). Modifications of this practice can be used to hasten the development of habitat with old-growth characteristics across thousands of

acres of young and middle-aged timber (Tappeiner 1992, Record of Decision 1994, Cole 1996). Few studies have compared the non-economic aspects of thinned stands to unthinned (pole) or to old-growth stands; the relative effects of thinning upon arthropod community composition and diversity are largely unstudied. Thinning needs to be evaluated for its effectiveness in recreating old-growth characteristics (as described in Spies and Franklin 1991), maintaining ecosystem functions, and promoting the species diversity and the richness characteristic of old-growth.

This study addresses the question of how thinning alters the biological diversity and community composition of soil and litter arthropods compared to unthinned mid-age and old-growth stands. Arthropods are integral parts of a functioning forest ecosystem and perform key roles as detritivores, herbivores, predators and prey. Soil and litter arthropods regulate rates of nutrient cycling, decomposition and energy flow (Wardle and Giller 1996, Seastedt 1984, Moldenke *et al.* 1994, Christiansen *et al.* 1989). These ecosystem variables in turn affect the allocation of carbon, canopy leaf area and rates of photosynthesis, ultimately affecting plant growth, species diversity, community composition and site productivity (see Fig. 2.1) (Kimmins 1996, Thompson *et al.* 1994, Setala and Huhta, 1991). Several studies have demonstrated that biological diversity is beneficial for ecosystem functioning and sustainability (Kareiva 1996, Tilman *et al.* 1996, Tilman and Downing 1994, Vitousek and Hooper 1993, McNaughton 1993, Naeem *et al.*, 1994, Wilson 1992, Chapin *et al.* 1995). If the soil and the community of organisms that live there are significantly altered in a way that impairs ecosystem function, then the sustainability of the ecosystem and resource values will be reduced (Kimmins

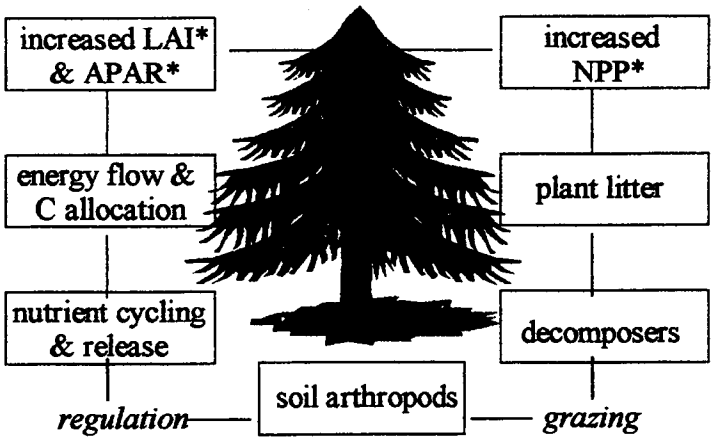


Fig. 2.1 Schematic of soil arthropods and ecosystem processes. *(leaf area index (LAI); absorbed photosynthetically active radiation (APAR); net primary production (NPP))

1996). The overall objective of this study is to provide information regarding the potential of thinning to enhance or impair ecosystem functioning and sustainability in Pacific Northwest forests.

Methods

Study areas

This research was conducted in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests on Bureau of Land Management (BLM) and US Forest Service (USFS) lands in the Cascade, Coast and Siskiyou Ranges of western Oregon. A total of twenty-seven sites were selected with the assistance of BLM employees and measured in the spring and summer of 1994. Aerial photos, stand history, current stand management, location, and slope were criteria used to select sites. Three triads were identified in each

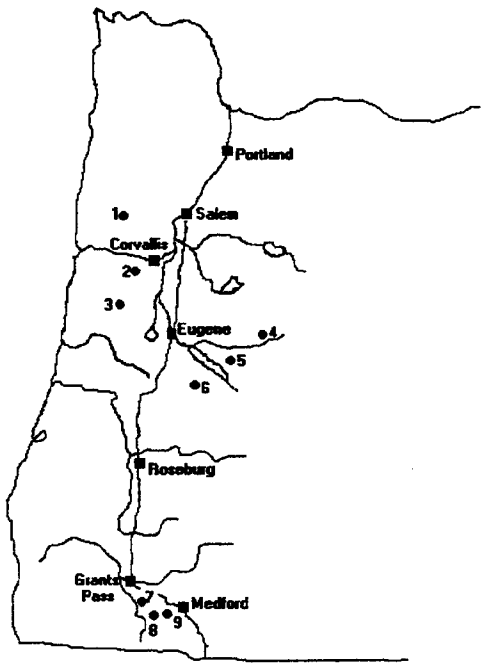


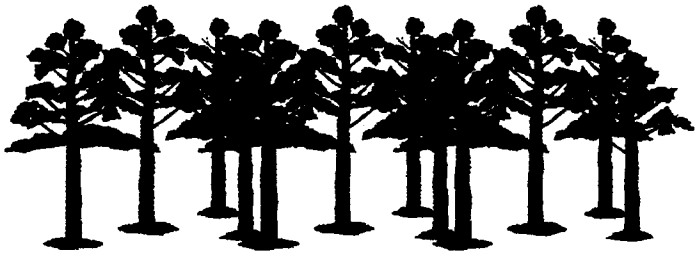
Fig. 2.2. Triad locations in Western Oregon.
Coast Range: 1- Sand Creek, 2- Mary's Peak, 3- Triangle Lake
Cascades: 4- H.J. Andrews, 5- Marten Ridge, 6- Eagles Rest
Southern OR: 7- Panther Gap, 8- Thompson Creek, 9- Buncom

region (Fig. 2.2). Each triad contained three treatments: an unthinned mid-aged stand, a thinned mid-aged stand, and an old-growth stand. Stands within a triad were located as closely as possible to each other, preferably with similar slopes and aspects.

Precipitation was primarily in the form of rain and temperatures tended to be mild at all sites. Weather and temperature data were taken from the Western Regional Climate Center web page (McCurdy 1997). Total annual precipitation in Southern Oregon averages 79 cm and total annual snowfall averages 10.7 cm. The annual high temperature for Southern Oregon is 68.5 °F and the annual low is 40.8 °F. Sites in the Cascades received the highest amount of precipitation with an annual total of 190.2 cm and 89.9 cm/year average snowfall. Temperatures in the Cascades ranged from an annual average

high of 64.1 °F to an average annual low of 37.7 °F. Sites in the Coast Range received an average total precipitation of 103.7 cm/year and 16.0 cm total annual snowfall. Temperatures ranged between an annual average high of 62.9°F and an annual average low of 40.8°F. Most sites were within the Western Hemlock Zone (Franklin and Dyrness 1984 as quoted by Bailey 1996) where hemlock (*Tsuga heterophylla* (Raf.) Sarg.) is considered climax. Several of the southern sites were in, or near transition into, the

Old growth stand



Mid-aged pole stand

Unevenly thinned stand

Old-growth:

Multi-storied canopy
Gaps
Over 100 years old

Unthinned (pole):

Reseeded naturally after disturbance
Single canopy layer
No gaps
40-50 years old

Thinned stand:

Pole stand that was thinned 10-15 years ago
Multi-storied canopy
Gaps
Mimics old-growth

Figure 2.3. Schematic of management

Douglas-Fir Zone (Franklin and Dryness 1984 as quoted by Bailey 1996), with Douglas-fir as the climax species.

Old-growth stands were defined as over 100 years old, with multi-layered canopies, light gaps and minimal disturbance (Fig. 2.3, Table 2.2). Mid-aged (pole) stands had reseeded naturally following either harvest or fire in the late 1800's and early 1900's (Bailey 1996). Mid-aged stands were between 50 to 90 years old, dominated by an one-age cohort, with a single canopy layer and no light gaps (Tables 2.3-2.4). Thinning was conducted between 1971 and 1985, depending on the stand. Thinnings were moderately heavy (20 to 51% merchantable volume removal, respectively) (Bailey 1996), resulting in development of an understory shrub layer (Tables 2.2-2.4). No additional treatments (e.g. fertilization) were recorded in either the thinned or unthinned stands (Bailey 1996).

Bailey (1996), in a coordinated study, described the vegetation found within each of the stands and compared vegetation composition and structure between treatments. Tables 2.1 to 2.10 were created from data tables found in his thesis and give a numerical description of individual stand histories and characteristics.

In summary, Bailey found that thinning did promote old-growth forest structure in terms of larger trees at lower densities and enhanced tree growth rates (Table 2.4). He also found that thinning at these sites had created multi-storied canopies with a multi-species subcanopy with potential for future contribution to the canopy itself (Tables 2.5-2.7). Harvesting activity or burning in the past was not found to impact site productivity in terms of volume or biomass production.

Table 2.1 Table of stand thinning histories and density. Taken from J. D. Bailey's Ph.D. thesis data (1996).
BLM district and legal location (township; range; section), age, year of commercial thinning, years since thinning, percent volume removed in that thinning, site index (base age 50).

Stand	BLM District	Location	Age	Year of commercial thinning	Years since thinning	% of volume removed	SI_{50}
Beaver Flat	Salem	13s-6w-19	50	1974	20	51	130
Triangle Lake (Gnome)	Eugene	16s-8w-1	60	1983	11	43	120
Sand Creek	Salem	8s-7w-31	70	1971	23	32	128
Marten Ridge	Eugene	17s-3e-6	70	1981	13	50	127
Eagle's Rest	Eugene	20s-1w-1	90	1974	20	50	90
Panther Gap	Medford	39s-5w-12	120	1981	13	20	78
Thompson Creek	Medford	39s-4w-3	110	1989	5	N/A	75
Buncom	Medford	38s-2w-31	120	1975	19	N/A	67
H.J. Andrews*	Eugene	------	-----	-----	----	----	----
		Min:	50	1971	5	20	67
		Max:	120	1989	23	51	130
		Avg:	86	1979	16	41	102
		Std:	28	6	6	13	27

*Information currently unavailable

Table 2.2 Table of old-growth stand density and overstory characteristics. Taken from J. D. Bailey's Ph.D. thesis data (1996). Stand-level averages for overstory (>8" DBH) tree and stand variables: trees per hectare, basal area per hectare (m2/ha), summed leaf area across all vegetation types (LA), crown radius (CRAD), current relative density index (RD), live crown ratio (LCR), and canopy leaf area index (CLA).

Stand: Old-growth	Overstory trees trees/ha	m^2/ha	LA	CRAD	RD	LCR	CLA
Beaver Flat	47	61	6.8	18	0.46	0.56	4.6
Triangle Lake (Gnome)	64	57	7.9	10	0.46	0.44	6.0
Sand Creek	54	65	7.2	18	0.50	0.49	6.4
Marten Ridge	69	62	N/A	16	0.50	0.46	N/A
Eagle's Rest	96	74	7.8	12	0.62	0.42	6.9
Panther Gap	89	40	4.0	14	0.37	0.38	3.4
Thompson Creek	N/A	N/A	N/A	17	0.31	0.35	3.8
Buncom	N/A	N/A	N/A	15	0.36	0.40	3.4
H.J. Andrews*	-----	-----	-----	----	-----	-----	----
Min:	47	40	4.0	10	0.31	0.35	3.4
Max:	96	74	7.9	18	0.62	0.56	6.9
Avg:	70	60	6.7	15	0.45	0.44	4.9
Std:	19.28	11.27	1.6	2.90	0.10	0.07	1.49

*Information unavailable

Table 2.3 Table of unthinned (pole) stand density and overstory characteristics. Taken from J. D. Bailey's Ph.D. thesis data (1996). Stand-level averages for overstory (>8" DBH) tree and stand variables: trees per hectare, basal area per hectare (m2/ha), summed leaf area across all vegetation types (LA), crown radius (CRAD), current relative density index (RD), live crown ratio (LCR), and canopy leaf area index (CLA).

Stand: Unthinned (pole) Overstory trees

	trees/ha	m^2/ha	LA	CRAD	RD	LCR	CLA
Beaver Flat	323	51	6.2	11	0.58	0.32	5.8
Triangle Lake (Gnome)	494	48	7.5	8	0.61	0.31	7.1
Sand Creek	415	62	6.1	10	0.71	0.29	5.4
Marten Ridge	272	65	6.4	12	0.68	0.36	4.4
Eagle's Rest	146	42	6.8	12	0.42	0.45	5.4
Panther Gap	156	27	3.6	11	0.30	0.25	3.4
Thompson Creek	N/A	N/A	N/A	7	0.34	0.24	3.7
Buncom	N/A	N/A	N/A	11	0.38	0.23	3.5
H.J. Andrews*	-----	-----	-----	----	-----	-----	----
Min:	146	27	3.6	7	0.30	0.23	3.4
Max:	494	65	7.5	12	0.71	0.45	7.1
Avg:	301	49	6.1	10	0.50	0.31	4.8
Std:	139.01	13.88	1.3	1.95	0.16	0.07	1.31

*Information unavailable

Table 2.4 Table of thinned stand density and overstory characteristics. Taken from J. D. Bailey's Ph.D. thesis data (1996). Stand-level averages for overstory (>8" DBH) tree and stand variables: trees per hectare, basal area per hectare (m2/ha), summed leaf area across all vegetation types (LA), crown radius (CRAD), current relative density index (RD), live crown ratio (LCR), and canopy leaf area index (CLA).

Stand: Thinned	Overstory trees trees/ha	m^2/ha	LA	CRAD	RD	LCR	CLA
Beaver Flat	151	32	6.2	15	0.34	0.47	5.0
Triangle Lake (Gnome)	146	20	6.5	11	0.23	0.37	3.8
Sand Creek	289	55	6.1	13	0.60	0.36	4.7
Marten Ridge	59	25	5.1	16	0.23	0.41	2.0
Eagle's Rest	77	24	7.9	16	0.24	0.48	5.9
Panther Gap	99	25	2.6	14	0.26	0.35	2.0
Thompson Creek	N/A	N/A	N/A	13	0.39	0.35	4.1
Buncom	N/A	N/A	N/A	11	0.28	0.44	2.5
H.J. Andrews*	-----	-----	-----	----	-----	-----	----
Min:	59	20	2.6	11	0.23	0.35	2.0
Max:	289	55	7.9	16	0.60	0.48	5.9
Avg:	137	30	5.7	14	0.32	0.40	3.8
Std:	83.08	12.77	1.8	2.06	0.13	0.05	1.46

*Information unavailable

Table 2.5 Table of old-growth stand understory characteristics. Taken from J. D. Bailey's Ph.D. thesis data (1996). Stand-level averages for understory or "intermediate" (1-8" DBH) trees: total density per acre (#/ac), density of dead (dead) and living (live), calculated percent living growth (%lv), and their live crown ratio (iLCR); and Stand-level averages for understory vegetation: density of tall shrubs per acre (S/A), tall shrub leaf area index (TSL), percent low or "small" shrub cover (SSC), small shrub leaf area index (SSL), and seedling density per acre (#SD).

Stand: Old-growth	Understory (intermediate) trees					Understory shrubs and seedlings				
	#/ac	dead	live	%lv	iLCR	S/A	TSL	SSC	SSL	#SD
Beaver Flat	49	0	49	100	0.59	847	0.7	43	1.5	64
Triangle Lake (Gnome)	50	3	47	94	0.51	1556	0.6	73	1.3	82
Sand Creek	32	4	28	88	0.59	1551	0.1	48	0.7	356
Marten Ridge	104	4	100	96	0.54	709	N/A	55	N/A	1562
Eagle's Rest	90	21	69	77	0.38	453	0.2	52	0.7	46
Panther Gap	241	97	144	60	0.23	746	0.1	17	0.5	224
Thompson Creek	N/A	0	N/A	N/A	0.54	1199	0.1	39	0.5	339
Buncom	N/A	8	N/A	N/A	0.40	1256	0.3	13	0.8	295
H.J. Andrews*	-----	----	-----	-----	-----	-----	----	----	----	----
Min:	32	0	28	60	0.23	453	0.10	13	0.50	46
Max:	241	97	144	100	0.59	1556	0.70	73	1.50	1562
Avg:	94	17	73	86	0.47	1039.63	0.30	42.5	0.86	371
Std:	77	33	43	15	0.13	410	0.25	20	0.39	497

*Information unavailable

Table 2.6 Table of unthinned (pole) stand understory characteristics. Taken from J. D. Bailey's Ph.D. thesis data (1996). Stand-level averages for understory or "intermediate" (1-8" DBH) trees: total density per acre (#/ac), density of dead (dead) and living (live), calculated percent living growth (%lv), and their live crown ratio (iLCR); and Stand-level averages for understory vegetation: density of tall shrubs per acre (S/A), tall shrub leaf area index (TSL), percent low or "small" shrub cover (SSC), small shrub leaf area index (SSL), and seedling density per acre (#SD).

Stand: Unthinned (pole)	Understory (intermediate) trees					Understory shrubs and seedlings				
	#/ac	dead	live	%lv	iLCR	S/A	TSL	SSC	SSL	#SD
Beaver Flat	55	48	7	13	0.37	247	0.1	40	0.3	169
Triangle Lake (Gnome)	262	141	121	46	0.30	388	0.2	24	0.2	51
Sand Creek	23	18	5	22	0.35	215	0.1	35	0.6	37
Marten Ridge	17	10	7	41	0.56	1219	0.3	81	1.7	0
Eagle's Rest	96	37	59	61	0.35	615	0.1	79	1.3	46
Panther Gap	149	64	85	57	0.25	585	0.0	14	0.2	97
Thompson Creek	N/A	16	N/A	N/A	0.24	81	0	0	0.1	0
Buncom	N/A	3	N/A	N/A	0.36	132	0	41	0.0	0.1
H.J. Andrews*	-----	----	-----	-----	-----	-----	----	----	----	----
Min:	17	3	5	13	0.238	81	0.00	0	0.00	0
Max:	262	141	121	61	0.56	1219	0.30	81	1.70	169
Avg:	100	42	47	40	0.35	435	0.10	39	0.55	50
Std:	93	45	49	19	0.10	373	0.11	29	0.62	59

*Information unavailable

Table 2.7 Table of thinned stand understory characteristics. Taken from J. D. Bailey's Ph.D. thesis data (1996).
Stand-level averages for understory or "intermediate" (1-8" DBH) trees: total density per acre (#/ac), density of dead (dead) and living (live), calculated percent living growth (%lv), and their live crown ratio (iLCR); and Stand-level averages for understory vegetation: density of tall shrubs per acre (S/A), tall shrub leaf area index (TSL), percent low or "small" shrub cover (SSC), small shrub leaf area index (SSL), and seedling density per acre (#SD).

Stand: Thinned	Understory (intermediate) trees					Understory shrubs and seedlings				
	#/ac	dead	live	%lv	iLCR	S/A	TSL	SSC	SSL	#SD
Beaver Flat	19	6	13	68	0.71	325	0.2	80	1.0	371
Triangle Lake (Gnome)	41	3	38	93	0.66	1775	0.4	85	2.3	332
Sand Creek	30	5	25	83	0.67	239	0.4	47	1.0	890
Marten Ridge	33	2	31	94	0.60	1584	0.4	95	2.7	174
Eagle's Rest	134	6	128	96	0.65	1172	0.7	70	1.3	801
Panther Gap	98	0	98	100	0.77	1205	0.5	11	0.1	1129
Thompson Creek	N/A	8	N/A	N/A	0.38	114	0	2	0	636
Buncom	N/A	10	N/A	N/A	0.46	397	0.2	4	0	1231
H.J. Andrews*	-----	----	-----	-----	----	----	----	---	---	-----
*Information unavailable										
Min:	19	0	13	68	0.38	114	0.0	2	0.00	174
Max:	134	10	128	100	0.77	1775	0.7	95	2.70	1231
Avg:	59	5	56	89	0.61	851.375	0.4	49	1.05	696
Std:	46	3	46	12	0.13	657	0.2	39	1.03	385

Table 2.8 Table of old-growth downed wood and hardwood densities. Taken from J. D. Bailey's Ph.D. thesis data (1996). Stand-level averages for downed wood debris and hardwoods: total volume of downed wood debris in cubic feet per acre (TOTAL), volume of decay class 4 and 5 material (ROTTEN), volume decay class 1-3 material (HARD), and percent of basal area comprised of hardwood species (%HWD).

Stand: Old-growth

	TOTAL	ROTTEN	HARD	%HWD
Beaver Flat	3643	2747	896	4
Triangle Lake (Gnome)	7257	5541	1715	1
Sand Creek	17185	17000	185	0
Marten Ridge	10069	5079	4990	1
Eagle's Rest	1557	1416	141	3
Panther Gap	5960	N/A	N/A	5
Thompson Creek	4714	N/A	N/A	N/A
Buncom	4488	N/A	N/A	N/A
H.J. Andrews*	-----	-----	-----	-----

*Information unavailable

Min:	1557	1416	141	0
Max:	17185	17000	4990	5
Avg:	6859	6357	1585	2
Std:	4878	6185	2008	2

Table 2.9 Table of unthinned (pole) downed wood and hardwood densities. Taken from J. D. Bailey's Ph.D. thesis data (1996). Stand-level averages for downed wood debris and hardwoods: total volume of downed wood debris in cubic feet per acre (TOTAL), volume of decay class 4 and 5 material (ROTTEN), volume decay class 1-3 material (HARD), and percent of basal area comprised of hardwood species (%HWD).

Stand: Unthinned (pole)

	TOTAL	ROTTEN	HARD	%HWD
Beaver Flat	6595	3827	2768	0
Triangle Lake (Gnome)	4738	3411	1327	1
Sand Creek	3360	2001	1359	1
Marten Ridge	867	623	245	3
Eagle's Rest	2090	2004	86	8
Panther Gap	902	N/A	N/A	8
Thompson Creek	747	N/A	N/A	N/A
Buncom	3606	N/A	N/A	N/A
H.J. Andrews*	-----	-----	-----	-----

*Information unavailable

Min:	747	623	86	0
Max:	6595	3827	2768	8
Avg:	2863	2373	1157	4
Std:	2109	1278	1077	4

Table 2.10 Table of thinned downed wood and hardwood densities. Taken from J. D. Bailey's Ph.D. thesis data (1996). Stand-level averages for downed wood debris and hardwoods: total volume of downed wood debris in cubic feet per acre (TOTAL), volume of decay class 4 and 5 material (ROTTEN), volume decay class 1-3 material (HARD), and percent of basal area comprised of hardwood species (%HWD).

Stand: Thinned

	TOTAL	ROTTEN	HARD	%HWD
Beaver Flat	5526	4943	283	0
Triangle Lake (Gnome)	3422	2902	520	1
Sand Creek	3638	3227	411	1
Marten Ridge	1262	967	295	1
Eagle's Rest	9095	8987	108	1
Panther Gap	3938	N/A	N/A	3
Thompson Creek	N/A	N/A	N/A	N/A
Buncom	1936	N/A	N/A	N/A
H.J. Andrews*	-----	-----	-----	-----
*Information unavailable				
Min:	1262	967	108	0
Max:	9095	8987	520	3
Avg:	3602	4205	323	1
Std:	2809	3023	154	1

Bailey (1996) found that the sub-canopy species composition and structure did significantly differ between thinned and unthinned treatments. Stands in both treatments were of similar densities, but there were greater numbers of dead or dying trees within unthinned stands versus the advanced regeneration found within the thinned stands (Tables 2.8-2.10). Canopy leaf area within thinned stands was half or less than that of unthinned stands, whereas old-growth stands carried more leaf area than unthinned stands (Tables 2.2-2.4).

Thinned stands typically had an order of magnitude higher density of seedlings than unthinned stands, where regeneration was sparse. Old-growth stands had seedling densities that were only marginally less than thinned stands. However, seedling species composition was different between the two treatments and height growth was significantly less within old-growth stands. Hardwood sprouts were found to be consistently more numerous and common in thinned than unthinned or old-growth stands (Tables 2.5-2.7).

Tall-shrub densities were highly variable across all sites, but with higher stem densities and frequencies of all species within thinned and old-growth stands. Low-shrub and fern cover, as well as leaf area, was dramatically higher in thinned stands after "10+" years, due primarily to the expansion of bracken fern and salal. Multivariate ordinations showed that thinned stands had a somewhat non-overlapping mix of shrub species relative to unthinned and old-growth stands.

Thinning stimulated herbaceous cover and frequency of some species groups, but no major compositional changes were found between treatment types. Relatively speaking, overall, old-growth and unthinned herbaceous communities were very similar in terms of total cover, species richness and the frequency of individual species/groups (Bailey 1996).

Field and laboratory methods

All samples were taken along a 250 meter transect line established within each stand. Transects were established using a compass to walk a line across a stand, running perpendicular to the slope. Ravines and streambeds were avoided. A minimum distance of 10m from the stand edge was maintained. Occasionally, it was not possible to meet all these criteria with a single line. In these cases, the line was interrupted and two parallel segments (at least 20 m apart) were set. There were fifty sampling points per transect, 5 meters apart. Average stand size was 18 acres.

Arthropod species diversity and abundance were measured using five sampling methods. Pitfalls were set to capture terrestrial macrofauna. Soil cores and litter samples were taken to measure soil and litter mesofauna. Beating and sweep net samples were taken to sample herbaceous and shrub arthropods. Lastly, black lights were set to capture nocturnal flying insects. The latter two methods and results are not discussed in this paper. The rest of the methods are expanded upon below.

Pitfall traps

Twenty-five pitfall traps were set 10 m apart at each site to capture terrestrial macroarthropods, such as millipedes (e.g. *Harpaphe spp.*, *Nearctodesmus spp.*), beetles (e.g. *Pterostichus spp.*), camel-crickets (e.g. *Pristoceuthophilus spp.)* and spiders (e.g. *Antrodiaetus spp.*). A one-quart yogurt (1100 cc) container was buried in the ground to the depth where the rim was level with the soil. An eight-ounce (liquid ounces = 0.25 l) cup containing an half inch (12 mm or 25 cc) of diluted antifreeze (ethylene glycol, 50% dilution) was placed at the bottom of the yogurt container. A metal funnel was placed

above the small cup, with the top flush with the rim. This design helped to ensure capture of arthropods, prevent escape and lessen the chance of capturing ground-dwelling vertebrates. A roof was placed above the yogurt container to keep rain out. Samples were collected three weeks after they were set. See Spence and Niemala (1994) for an in-depth discussion of this method.

Soil cores

Twenty-five soil cores were taken to sample soil mesofauna (e.g. Acari, Collembola, and small insects). Samples were taken 10 meters apart, at every other sampling point and alternating with the pitfall traps. After the litter layer was removed, a 7.5 cm. diameter core of soil, 10 cm. in depth, was taken with a hand trowel. Cores were placed in sealed plastic bags and then into 2-5° C cold storage. Arthropods were heat-extracted at a later date using Tullgren funnels. See Winter and Voroney (1993) for an in-depth discussion of this method.

Litter samples

A total of ten litter samples per site were taken at 25 meter intervals to measure litter mesofauna (e.g. Collembola, Acari, and small insects). 25 cm by 25 cm of litter and topsoil (depth variable) were placed in plastic bags and then in 2-5° C cold storage. Arthropods were heat-extracted at a later date using Tullgren funnels. See Winter and Voroney (1993) for an in-depth discussion of this method.

Sampling Schedule

Pitfall samples were taken at all twenty-seven sites during each sampling period (Table 2.11). The soil and litter communities were only sampled during the first sampling period due to lower population turnover rates through seasons (Moldenke and Fitcher 1988). Sampling dates were not replicated seasonally as it was assumed that any major treatment effect should be visible regardless of sampling date.

Table 2.11 Sampling schedule.

Date	Location	Samples Taken
June 1994	Southern Oregon	Pitfalls, soil cores, litter, beating and sweeping, black lights
July 1994	Cascades	Pitfalls, soil cores, litter, beat/sweep, black lights
August 1994	Coast Range	Pitfalls, soil cores, litter, beat/sweep, black lights
Fall 1994	Southern Oregon	Pitfalls, beating and sweeping, black lights
Fall 1994	Cascades	No sampling
Fall 1994	Coast Range	No sampling
Spring 1995	Southern Oregon	Pitfalls, beating and sweeping, black lights
Spring 1995	Cascades	Pitfalls, beating and sweeping, black lights
Spring 1995	Coast Range	Pitfalls, beating and sweeping, black lights
Fall 1995	Southern Oregon	Pitfalls, black lights
Fall 1995	Cascades	Pitfalls
Fall 1995	Coast Range	Pitfalls

Data Analysis

Ordinations were used to examine the overall pattern of arthropod communities within western Oregon and the effect of stand treatment. The main matrix consisted of count data of species occurrences within a trap or stand.

Relative estimates of species diversity and abundance were determined from count data of the individuals collected. Identifications were taken to species whenever possible and the rest were sorted into morphospecies for the purposes of this study.

Data were analyzed using the computer statistical package PCORD (McCune and Mefford 1995). Initially, a row and column summary was run to yield descriptive statistics

Table 2.12 Descriptive statistics for the main matrix of all stands, pitfall samples.

Parameter	Transformations					
	Before	<5%	Log, <5%	Presence-absence	Presence-absence, <5%	Beals smoothing <5%
ROWS sample units	79	79	79	79	79	79
Beta diversity	7.88	4.43	4.43	7.88	4.43	1.0
Average skewness	9.305	6.648	2.812	2.386	1.43	1.393
CV* of sums	604.69	437.43	219.53	258.26	181.42	86.12
COLUMNS species	205	104	104	205	104	104
Average skewness	6.053	4.627	2.803	4.250	1.783	.862
CV of sums	286.58	273.56	172.19	205.51	162.39	32.24

Coefficient of variation = CV = 100*standard deviation/mean

on the main matrix (Table 2.12). Beta diversity was greater than 2.0 (see Table 2.12), suggesting the use of Sorensen's index over an Euclidean distance measure. Elevated skewness and beta diversity, suggesting a mild zero-truncation problem, indicated the necessity for transformation. Initial ordinations were run on untransformed data in order to determine the effects of subsequent transformations upon the matrix. A variety of ordination methods and transformations, including Bray-Curtis (B-C) ordination, non-metric multi-dimensional scaling (NMS), detrended correspondence analysis (DCA), canonical correspondence analysis (CCA), hierarchical clustering and multi-response permutation procedures, were initially run to become familiar with the response of this data set to different analysis tools and to aid in determining the most appropriate method (Figs 2.4-2.11). All four ordination methods yielded similar ordination patterns when analyzing these data sets, with CCA (Fig. 2.10-2.11) providing the greatest clarity and DCA (Fig. 2.8-2.9) providing the least clarity.

Two different transformations of the entire data set were examined: a) log-transformations are useful when there is a high degree of variation among the samples and for reducing high skewness; such as is often seen among count data. (Prior to the log-transformation, a constant (+1) was added to the data set.); b) Beals Smoothing was the second transformation considered. This is a very powerful transformation, the purpose of which is to relieve the "zero-truncation" problem (Beals 1984). This transformation tends to reduce the noise in the data by enhancing the strongest patterns in the data and is particularly effective on heterogeneous or noisy data (McCune 1994). This transformation converts quantitative data to presence-absence data.

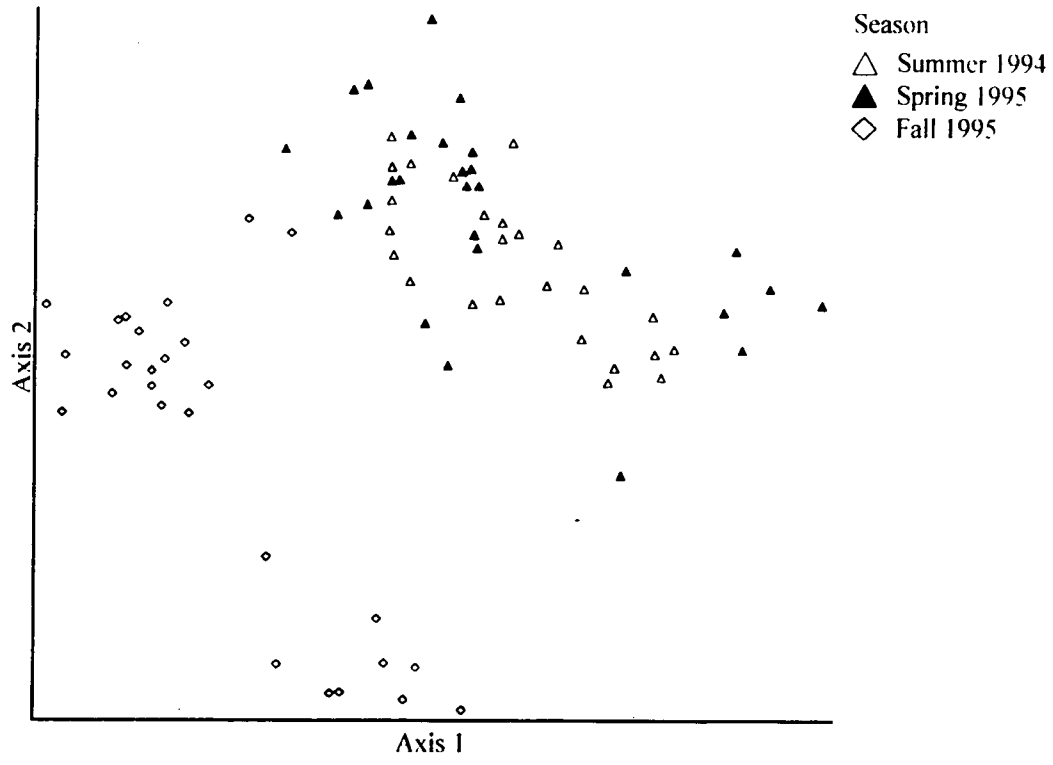


Fig. 2.4 Bray-Curtis ordination of all pitfall samples, log transformed, minus species occurring in less than 5% of all stands. (Separates Fall '95 on combination of axes 1 & 2)

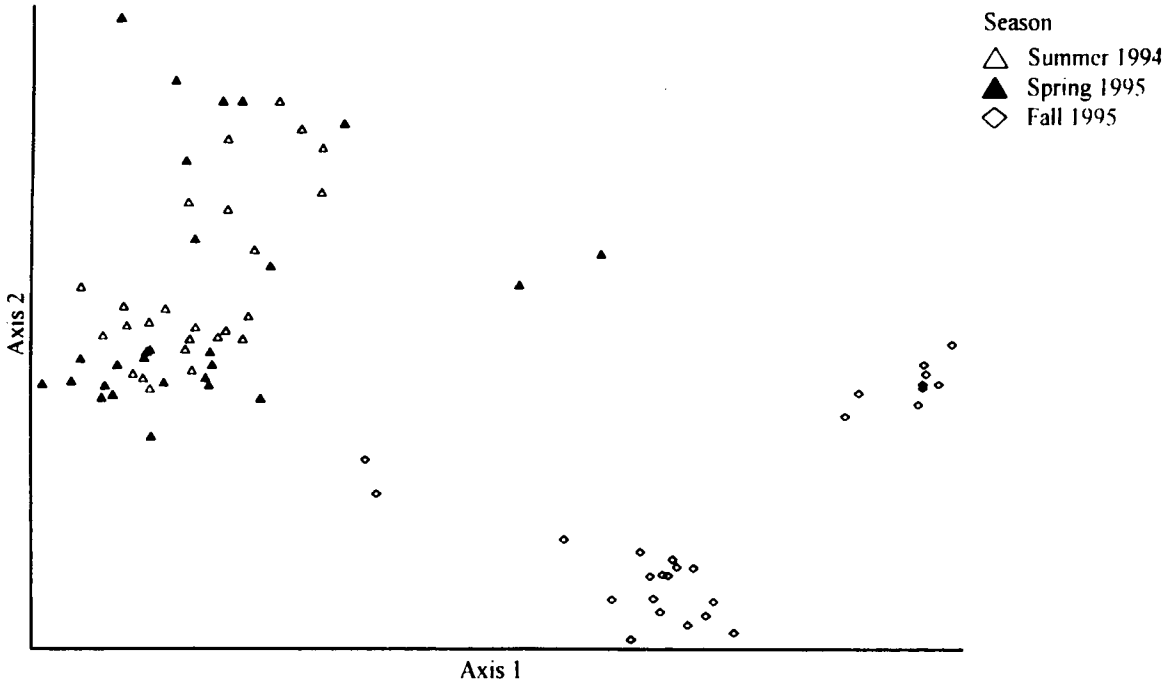


Fig. 2.5 Bray-Curtis ordination of all pitfall samples, Beals smoothing transformation, minus species occurring in less than 5% of all stands. (Separates Fall '95 on axis 1)

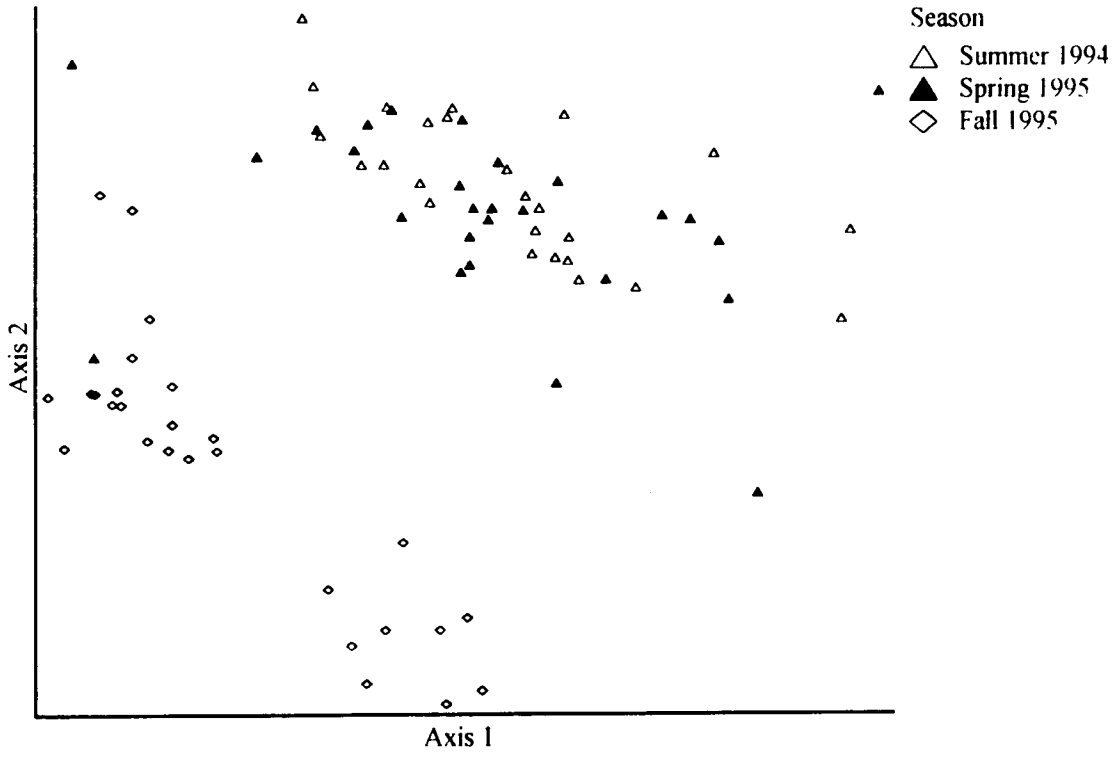


Fig. 2.6 NMS ordination of all pitfall samples, log transformed, minus species occurring in less than 5% of all stands. (Separates Fall '95 on axes 1 & 2)

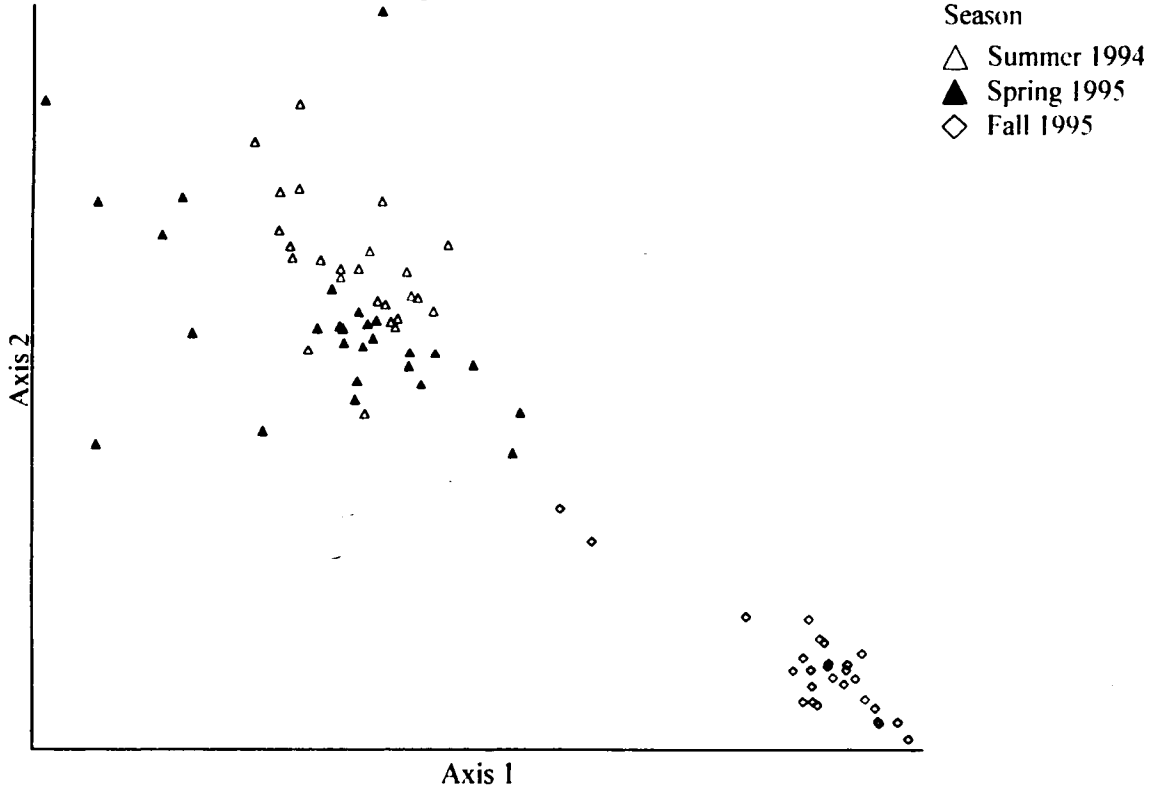


Fig. 2.7 NMS ordination of all pitfall samples, Beals smoothing transformation, minus species occurring in less than 5% of all stands. (Separates Fall '95 on axis 1 & axis 2)

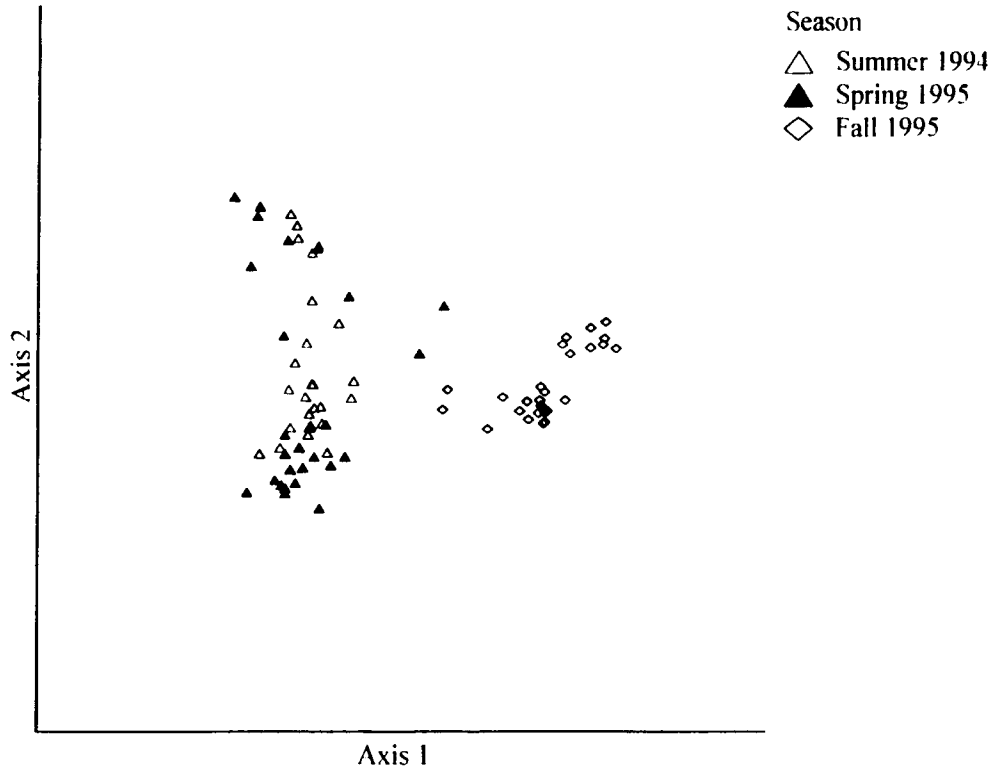


Fig. 2.8 DCA ordination of all pitfall samples, log transformed, minus species occurring in less than 5% of all stands. (Separates Fall '95 axis 1)

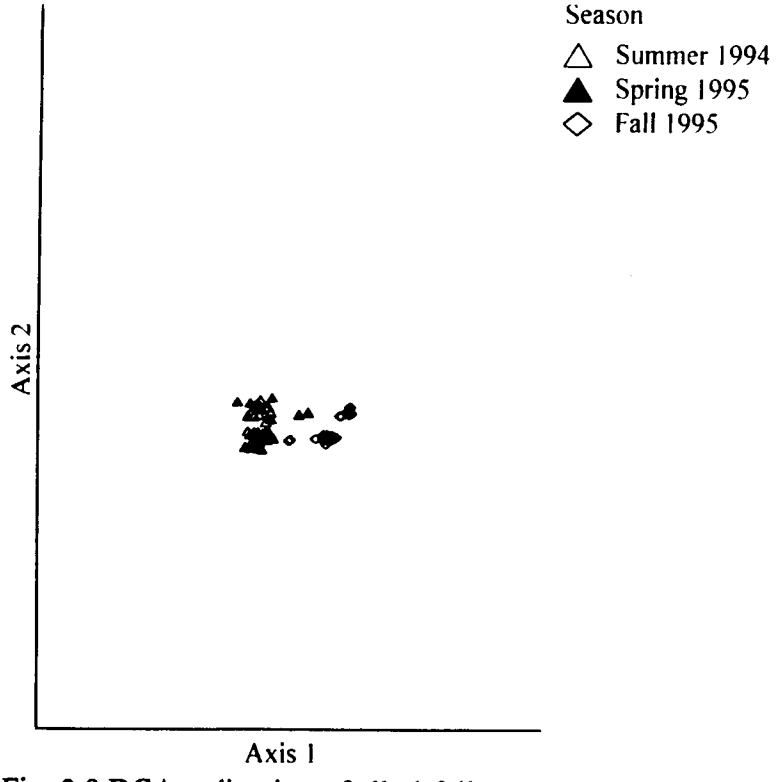


Fig. 2.9 DCA ordination of all pitfall samples, Beals smoothing transformation, minus species occurring in less than 5% of all stands.

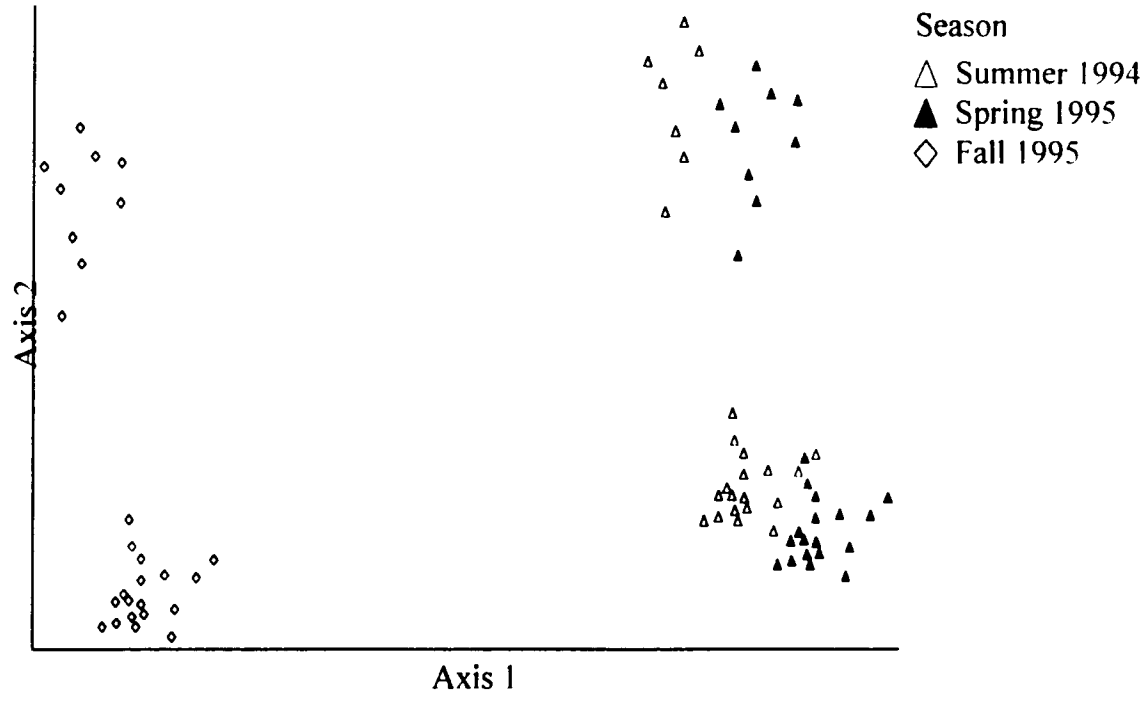


Fig. 2.10 CCA ordination of all pitfall samples, log transformed, minus species occurring in less than 5% of all stands. (Fall '95 separates on axis 1)

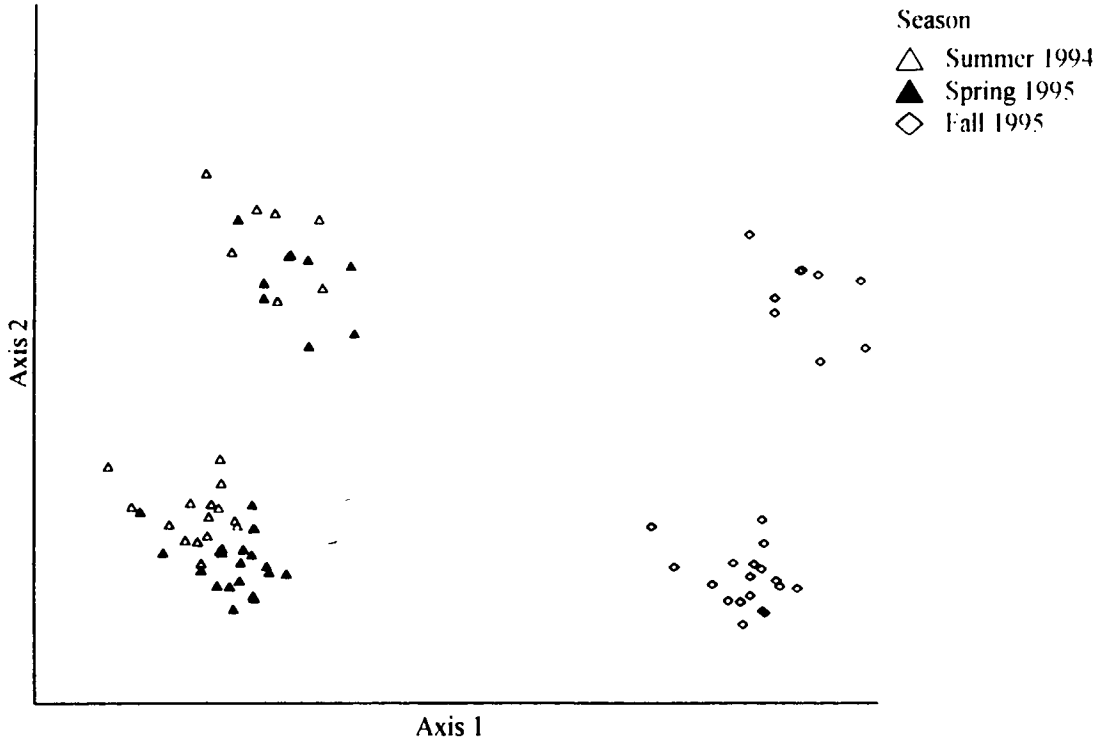


Fig. 2.11 CCA ordination of all pitfall samples, Beals smoothing transformation, minus species occurring in less than 5% of all stands. (Fall '95 separates on axis 1)

These data sets were comprised of non-normal, community data, with high skewness and beta diversity (Table 2.12). The matrices were count data of relative abundance of arthropods collected. Prior to all ordination methods, rare species, defined as occurring in 5% or less of the sample units, were deleted and data were transformed. The Beals smoothing was most effective with the Bray-Curtis ordination method, whereas the log-transformation was the most effective in enhancing patterns with the other three methods. As a result, CCA ordinations on log-transformed data were used to analyze the data sets in this study, since these methods yielded the ordinations with the greatest clarity. CCA also has the advantage of being the ordination technique used most often in the literature.

Canonical correspondence analysis (CCA) is an analytical method that is best suited to community data sets where the species response curves are unimodal (bell-shaped) and the important underlying environmental variables have been measured. This ordination method constrains samples and species by their relationships to environmental variables and performs a multiple regression of community gradients on environmental variables. CCA is based on a chi-squared distance measure where samples are weighted according to their totals (McCune 1996).

All CCA ordinations discussed in this paper used Hill's scaling to rescale site scores. Optimization of site scores (alpha=0) was the option chosen for scaling of the ordination. "Sample unit scores derived from taxa" was the option chosen for graphing. Monte Carlo tests, with 100 iterations, were run with each ordination to assure that no relationship existed between matrices.

Multi-response permutation procedures (MRPP) were also used to test the hypotheses of no difference within stands (old-growth, pole and thin), within regions (Southern Oregon, Cascades, and Coast Range) and within triads. A t-statistic and an associated p-value were generated in each case to assess the validity of the null hypothesis. The distance measure used was Euclidean.

Results

Arthropod species diversity and abundance

A total of 473 species, comprising 210,297 individuals, were collected in all during the entire study (Table 2.13). Litter samples and spring pitfall samples proved to be the most speciose, and individuals collected from the litter accounted for more than half of the number of the individuals. The three methods combined yielded a total of eighteen insect orders, ten other arthropod taxa and two other animal phyla, the Annelida and Mollusca (Table 2.14, Appendix). In total, over 179 families were collected.

Table 2.13 Totals: All stands (sorted by Collection Method)

Sampling Method	Total Spp	Total Indiv
Soil	176	37847
Litter	242	119665
Pitfalls Total	320	52785
Fall	154	10971
Spring	255	20138
Summer	220	21676
Total	473	210297

Table 2.14 **Totals: All stands (sorted by Order)**

Order	Total Indiv	Litter Spp	Litter Indiv	Soil Spp	Soil Indiv	Pitfalls Indiv	Fall Spp	Fall Indiv	Spring Spp	Spring Indiv	Summer Spp	Summer Indiv
Acari	4731	1	1	17	1666	3064	2	1600	2	416	4	1048
Acaridida	25	2	25	0	0	0	0	0	0	0	0	0
Actinedida	2482	9	2482	0	0	0	0	0	0	0	0	0
Annelida	72	2	24	1	16	32	2	17	2	9	1	6
Araneae	8119	9	539	6	38	7542	18	1970	52	2639	41	2933
Blattaria	2	0	0	0	0	2	0	0	1	1	1	1
Chilopoda	1863	2	610	2	77	1176	4	178	3	363	4	635
Coleoptera	17983	51	1229	32	323	16431	60	2700	101	8725	88	5006
Collembola	22401	15	18559	14	3842	0	0	0	0	0	0	0
Dermaptera	1	0	0	0	0	1	0	0	1	1	0	0
Diplopoda	4112	10	661	6	32	3419	12	547	16	1694	14	1178
Diplura	208	2	204	2	3	1	1	1	0	0	0	0
Diptera	853	13	586	9	226	41	1	1	3	33	3	7
Gamasida	4545	9	4545	0	0	0	0	0	0	0	0	0
Hemiptera	406	2	16	2	3	387	5	66	9	216	8	105
Homoptera	165	3	31	1	4	130	3	44	4	27	3	59
Hymenoptera	5183	13	335	5	26	4822	13	790	20	1251	23	2781
Isopoda	2095	1	69	0	0	2026	1	396	3	945	2	685
Isoptera	9	0	0	0	0	9	1	1	1	4	1	4
Ixodida	1	1	1	0	0	0	0	0	0	0	0	0
Lepidoptera	367	3	10	1	4	353	4	146	6	157	5	50
Mecoptera	12	0	0	0	0	12	0	0	1	12	0	0
Microcoryphia	1371	1	5	0	0	1366	1	332	2	1033	2138	1
Mollusca	2494	2	2	1	1	2491	5	723	5	1603	4	165

Table 2.14 con't.

Order	Total Indiv	Litter Spp	Litter Indiv	Soil Spp	Soil Indiv	Pitfalls Indiv	Fall Spp	Fall Indiv	Spring Spp	Spring Indiv	Summer Spp	Summer Indiv
Neuroptera	25	1	11	1	1	13	1	2	3	4	2	7
Opiliones	3947	7	108	2	7	3832	10	628	10	708	9	2496
Oribatida	116842	73	85803	66	31039	0	0	0	0	0	0	0
Orthoptera	3173	0	0	0	0	3173	3	661	3	248	1	2264
Pauropoda	225	2	135	1	90	0	0	0	0	0	0	0
Protura	1792	1	1452	1	340	0	0	0	0	0	0	0
Pseudoscorpiones	1889	4	1648	2	74	167	3	145	3	20	2	2
Psocoptera	197	1	105	2	24	68	1	1	2	9	1	58
Scorpionida	36	0	0	0	0	36	1	9	1	19	1	8
Siphonaptera	8	0	0	0	0	8	1	7	1	1	0	0
Symphyla	466	1	458	1	8	0	0	0	0	0	0	0
Thysanoptera	12	1	11	1	1	0	0	0	0	0	0	0

Table 2.15 Total # of Species & Individuals / Region

Region	Total Indiv	Litter Spp	Litter Indiv	Soil Spp	Soil Indiv	Pitfalls Indiv	Fall Spp	Fall Indiv	Spring Spp	Spring Indiv	Summer Spp	Summer Indiv
Southern Oregon	35876	129	9991	101	4281	21604	106	5095	191	7438	146	9071
Cascades	79455	181	49652	125	16576	13227	82	2423	123	5363	117	5441
Coast Range	94966	195	60022	127	16990	17954	92	3453	172	7337	136	7164

Litter mesoarthropods were most dense in the Coast Range (30,000/m^2); less dense in the Cascades (25,000/m^2); and the least dense in southern Oregon (5,000/m^2) (Table 2.15). Soil arthropods followed a similar trend: 70,000/m^2, 69,000/m^2, 15,000/m^2.

The Coast Range and Cascades were characterized by 1.5-fold more litter species and 1.3-fold more soil species than Southern Oregon. In contrast, macroarthropods from pitfall traps were both most abundant and most speciose in Southern Oregon, followed by the Coast Range, regardless of season (Table 2.15).

Relative numbers of species and individuals per triad followed similar trends within each region, reflecting regional patterns and totals (Table 2.16). Maximum species richness and abundance varied by treatment from triad to triad for all sampling methods (Table 2.17).

Table 2.18 shows that for litter mesoarthropods, density is nearly twice as great in old-growth, but species richness is virtually equivalent. For soil mesoarthropods there is no significant difference in either density or species richness with differing management types. Density of pitfall macroarthropods was greatest for thinned stands in fall, unthinned pole stands in spring and old-growth in summer. Species richness did not differ by stand management type during any season (Table 2.18).

Fungivores were by far the most speciose and abundant functional group in litter and soil samples, primarily due to the dominance of oribatid mites and springtails. Predators dominated the pitfall samples, being four times more speciose and ten times more abundant. This trend was consistent regardless of the season in which the sample was collected (Table 2.19).

Table 2.16 **Total # of Species & Individuals / Triad**

Triad	Total Indiv	Litter Spp	Litter Indiv	Soil Spp	Soil Indiv	Pitfalls Indiv	Fall Spp	Fall Indiv	Spring Spp	Spring Indiv	Summer Spp	Summer Indiv
Thompson Creek (SO)	9222	78	1179	60	637	7406	80	1290	120	2323	94	3793
Buncom (SO)	14308	93	3579	70	2112	8617	69	1774	111	2330	114	4513
Panther Gap (SO)	11746	90	4633	71	1532	5581	68	2031	99	2785	58	765
Eagles Rest (CA)	34671	153	24386	91	5587	4698	66	1040	85	1709	89	1949
Marten Ridge (CA)	34858	152	25266	86	4553	5039	54	863	82	1972	71	2204
H. J. Andrews (CA)	9926			85	6436	3490	52	520	71	1682	70	1288
Mary's Peak (CO)	27295	144	12608	105	8702	5985	48	860	83	2092	79	3033
Triangle Lake (CO)	36439	154	22265	98	8288	5886	68	1337	98	2286	93	2263
Sand Creek (CO)	31232	142	25149			6083	73	1256	126	2959	80	1868

Table 2.17 **Total # of Species & Individuals / Stand**

Stand	Total Indiv	Litter Spp	Litter Indiv	Soil Spp	Soil Indiv	Pitfalls Indiv	Fall Spp	Fall Indiv	Spring Spp	Spring Indiv	Summer Spp	Summer Indiv
Southern Oregon												
TCO	5579	78	1779	56	609	3191	54	437	65	823	51	1931
BUO	5252	65	1362	58	1280	2610	43	535	58	573	61	1502
PGO	5553	66	3726	44	504	1323	46	453	52	870		
TCP	2579			5	6	2573	44	347	65	1166	48	1060
BUP	5498	56	1902	37	818	2778	49	569	59	696	75	1513
PGP	2976	43	267	35	314	2395	41	781	55	849	58	765
TCT	1934			11	22	1912	45	506	63	604	73	802
BUT	3558	45	315	9	14	3229	48	670	80	1061	58	1498
PGT	3217	42	640	43	714	1863	49	797	69	1066		

Table 2.17 con't.	Total	Litter		Soil		Pitfalls	Fall		Spring		Summer	
Stand	Indiv	Spp	Indiv	Spp	Indiv	Indiv	Spp	Indiv	Spp	Indiv	Spp	Indiv
Cascades												
ERO	13690	115	9968	66	1800	1922	48	328	48	645	45	949
MRO	18925	104	16465	56	1570	890	32	193	49	440	37	257
HJO	3668			66	2381	1287	36	222	44	516	53	549
ERP	10405	103	6592	71	2397	1416	31	267	57	518	47	631
MRP	8907	116	5461	63	1534	1912	32	251	46	934	43	727
HJP	4244			65	3164	1080	32	131	45	475	29	474
MRT	7026	103	3340	67	1449	2237	38	419	61	598	52	1220
ERT	10576	128	7826	56	1390	1360	38	445	52	546	53	369
HJT	2014			46	891	1123	35	167	52	691	33	265
Coast Range												
MPO	4859	84	3445			1414	32	139	56	669	47	606
TLO	12190	112	7507	67	1836	2847	57	548	67	1106	66	1193
SCO	15622	107	14074			1548	44	410	50	574	39	564
MPP	8722	90	3284	72	2900	2538	38	423	55	772	60	1343
TLP	14569	101	9393	66	3699	1477	26	272	56	553	45	652
SCP	8455	90	5710			2745	45	372	61	1832	52	541
MPT	13714	107	5879	89	5802	2033	36	298	58	651	50	1084
TLT	9654	95	5365	62	2690	1599	44	517	65	627	50	455
SCT	7155	95	5365			1790	47	474	62	553	57	763

Table 2.18 **Average # of Species & Individuals / Treatment**

Stand	Total Indiv	Litter Spp	Litter Indiv	Soil Spp	Soil Indiv	Pitfalls Indiv	Fall Spp	Fall Indiv	Spring Spp	Spring Indiv	Summer Spp	Summer Indiv
Old-growth	10667	91	7291	59	1426	1892	44	363	54	691	50	944
Unthinned	9479	86	4658	52	1854	2102	38	379	55	866	51	856
Thinned	8407	88	4104	48	1622	1905	42	477	62	711	53	807

Table 2.19 **Totals: All stands (sorted by Functional Groups)**

Functional Group	Total Indiv	Litter Spp	Litter Indiv	Soil Spp	Soil Indiv	Pitfalls Indiv	Fall Spp	Fall Indiv	Spring Spp	Spring Indiv	Summer Spp	Summer Indiv
Bacteriovore	15491	14	10357	13	5134	0	0	0	0	0	0	0
Detritivore	12614	21	4456	17	1468	6690	18	1108	40	3474	30	2108
Fungivore	95500	86	67809	71	26455	1236	15	269	21	523	13	444
Herbivore	4466	22	914	13	56	3496	21	606	34	2272	29	618
Herbivore Moss	23	3	23	0	0	0	0	0	0	0	0	0
Lichenivore	3968	3	347	2	31	3590	3	335	3	1040	3	2215
Necrivore	85	0	0	0	0	85	2	2	2	71	1	12
Omnivore	31919	5	26050	1	3068	2801	6	625	11	812	9	1364
Parasite	3226	2	46	0	0	3180	4	1541	7	528	8	1111
Predator	39553	82	9634	59	1633	28286	79	5755	130	11120	120	11411
Slime Mold	7	3	7	0	0	0	0	0	0	0	0	0
Unknown*	3443	1	22	0	0	3421	6	730	7	298	7	2393

* This category consists primarily of camel crickets (*Pristoceuthophilus spp.*)

Arthropod community composition: Inter-regional results

Figures 2.10 and 2.11 are canonical correspondence analyses (CCA) of arthropod community composition. They display the pattern generated from a matrix of pitfall trap totals (count data of species occurrences), including all sampled regions, seasons, and treatments. The largest factor (x-axis values) determining the pattern of community composition was seasonality. Fall 1995 is isolated as a distinct grouping from the other two seasons, spring 1995 and summer 1994. When fall 1995 is removed from the ordination, distinct distributions between the other two seasons become apparent (not shown).

Region was the second-ranked determining factor (= y-axis) of arthropod community composition. Southern Oregon, in particular, was distinct from the other two regions, the Cascades and the Coast Range (Fig. 2.12). When both the Southern Oregon

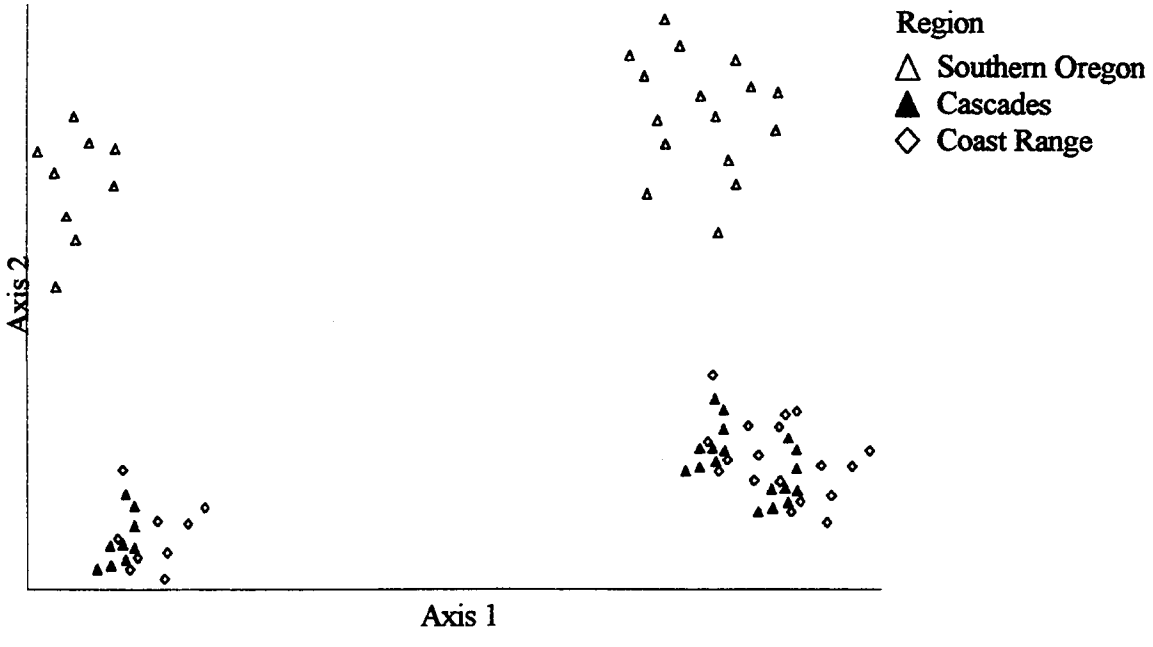


Fig. 2.12 CCA ordination, all pitfalls, log transformed, minus species occurring in less than 5% of all stands, grouped by region. (Southern Oregon separates on axis 2)

and Fall 1995 data points were removed from the ordination, season again becomes the primary factor determining community composition and region the secondary factor (not shown).

Locale (triad) had a low MRPP p-value (Table 2.20) and therefore can also be considered a determining factor of community composition, though it is not visually evident in the above figures. The effect of differing stand treatments was not visually discernible (Fig. 2.13) at this scale, with data present from the entire statewide design.

Table 2.20 MRPP p-values for inter-regional determinants of arthropod composition.

p-value (MRPP)	Season	Region	Locale (triad)	Treatment
<5%, BS	0.00001	0.00003	0.001	1.000
<5%, log	0.00001	0.00003	0.00005	0.878
untransformed	0.00001	0.00003	0.00005	0.369
p-value (Monte Carlo)	0.010	0.010	N/A	N/A

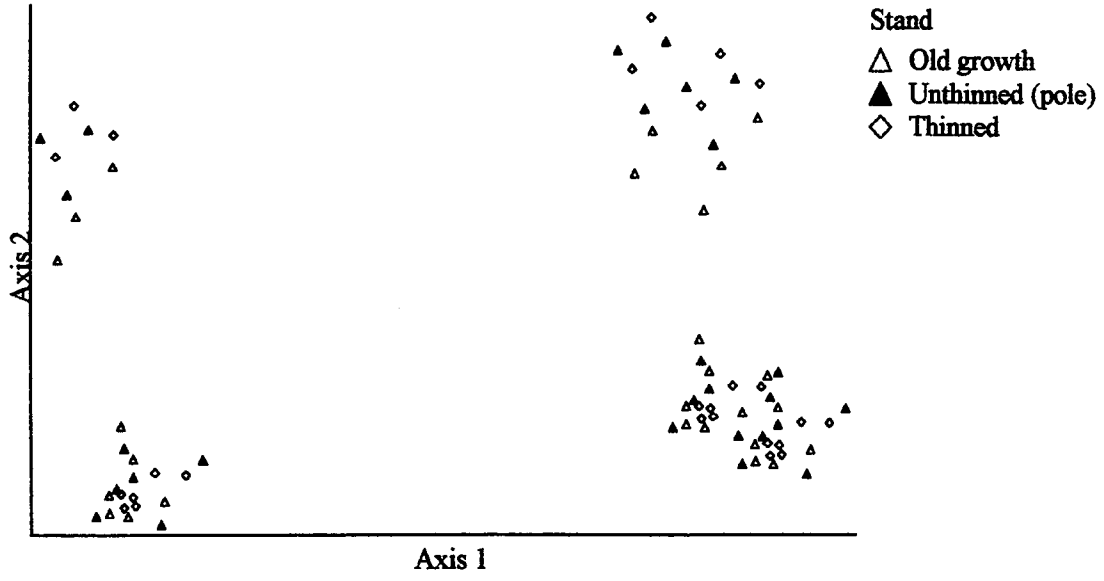


Fig. 2.13 CCA ordination, all pitfalls, log transformed, less species occurring in 5% or less of all stands, grouped by treatment.

CCA ordinations of the litter and soil communities across regions also revealed that region was the prime determinant and that Southern Oregon was the most distinct. The Cascades litter arthropod community was clearly intermediate between Southern Oregon and the Coast Range (Figs. 2.14-2.15). These methods were employed only during a single sampling season and region is thus the primary explanatory factor, even after Southern Oregon is removed from the ordinations (not shown).

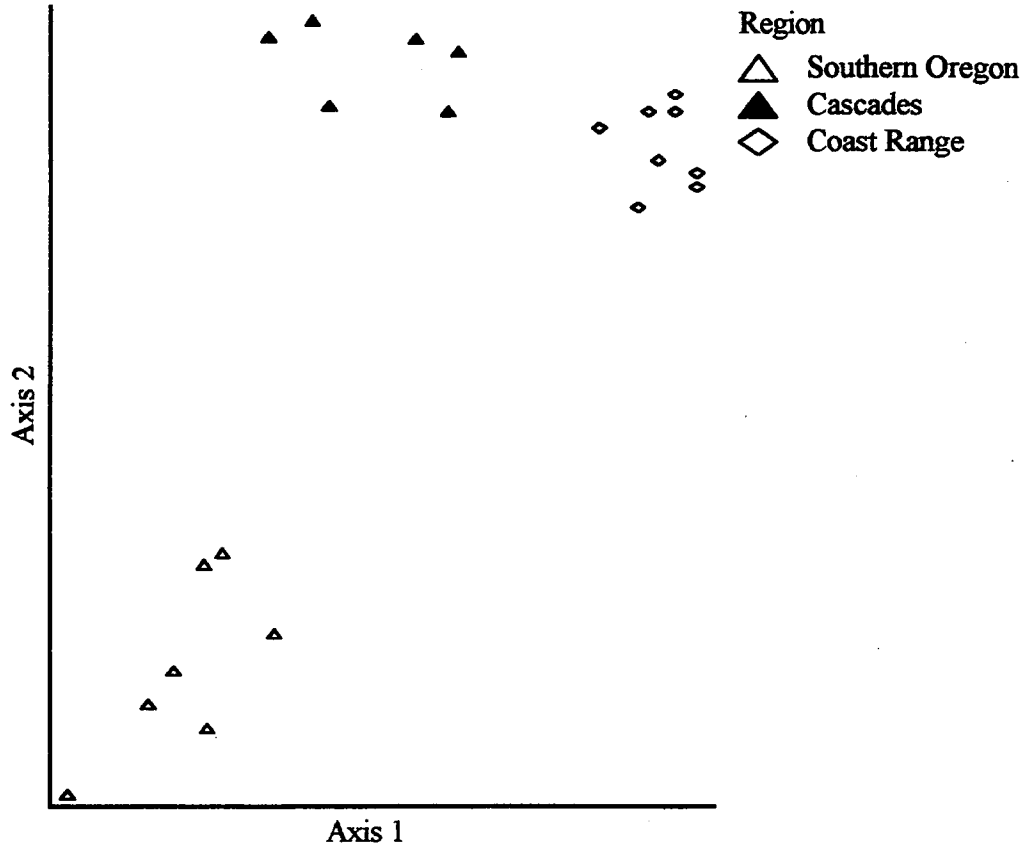


Fig. 2.14 CCA ordination, litter samples, log transformed, minus species occurring in less than 5% of all stands, grouped by region. (All three distinct on x-axis, Cascades intermediate; Southern Oregon distinct on y-axis as well.)

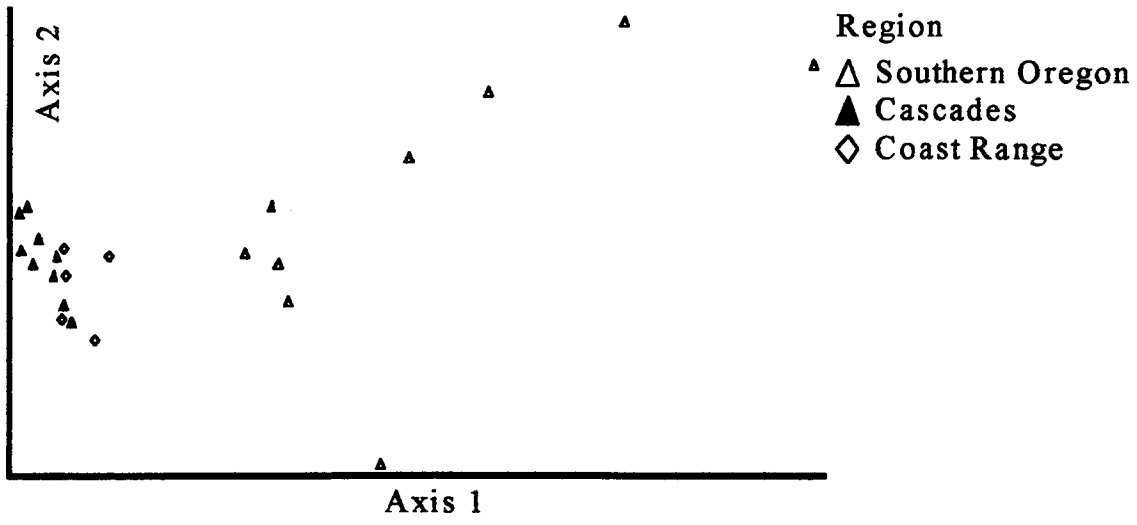


Fig. 2.15 CCA ordination, soil samples, log transformed, minus species occurring in less than 5% of all stands, grouped by region. (Southern Oregon is the most distinctive).

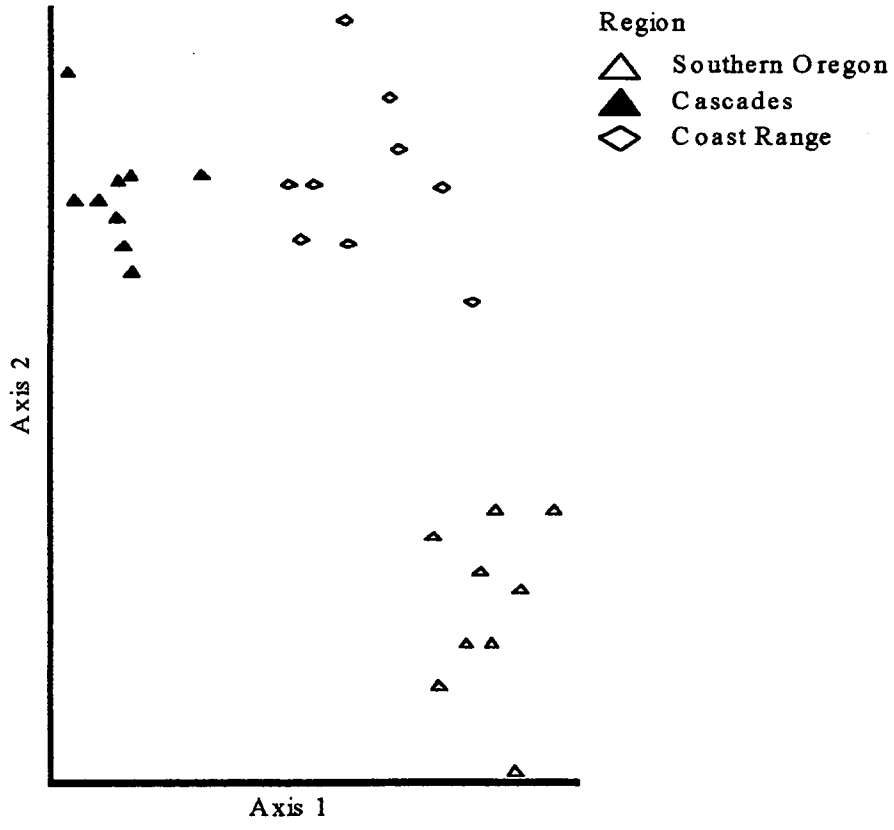


Fig. 2.16 CCA ordination, Fall pitfall samples, log transformed, minus species occurring in less than 5% of all stands, grouped by region. (Southern Oregon most distinct on axis 2; Coast Range intermediate between Southern Oregon and Cascades on axis 1).

Ordinations eliminating the seasonal effect, through examination of pitfall totals for all regions, but within a single sampling season, showed similar patterns of arthropod community composition as the seasons combined (Fig. 2.16). Region was again the primary explanatory factor determining the observed arthropod community composition, with no noticeable management effect. Coast Range pitfall samples were intermediate in composition to Southern Oregon and the Cascade pitfalls during fall.

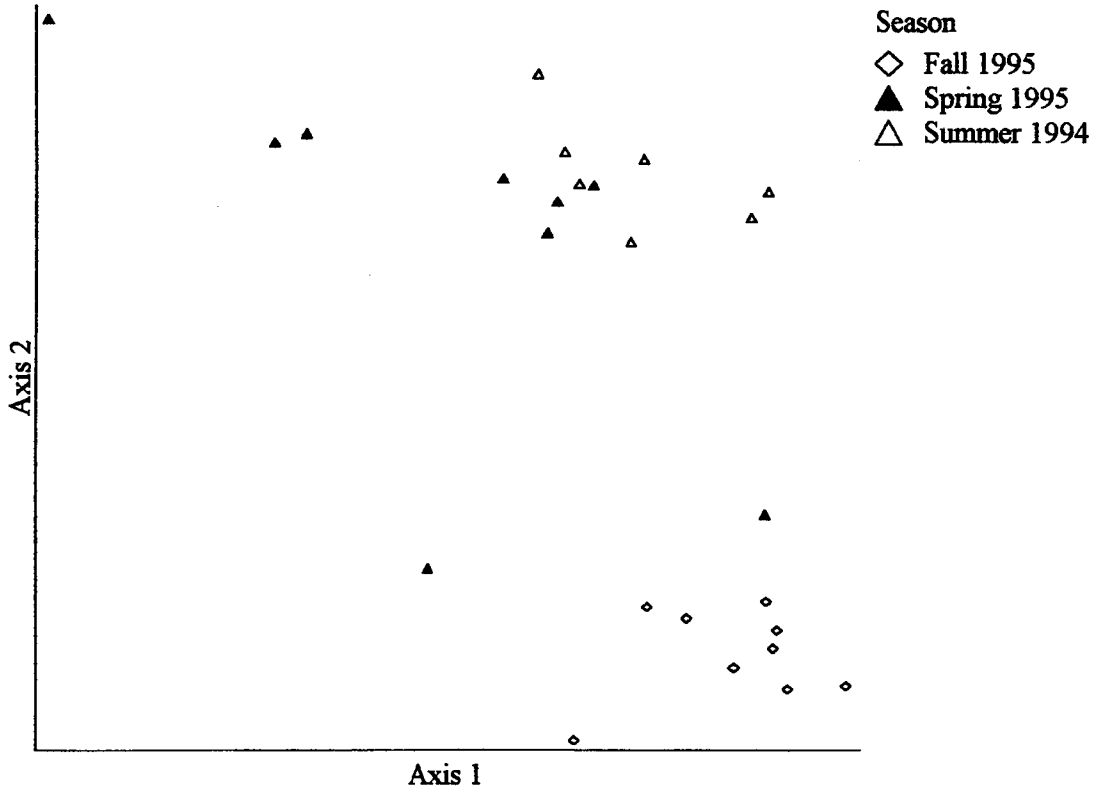


Fig. 2.17 CCA ordination, all Southern Oregon pitfalls, log transformed, minus species occurring in less than 5% of all stands, grouped by season.

Arthropod community composition: Intra-regional results

An ordination of all pitfall totals within Southern Oregon for all seasons displays a seasonal effect, with Spring most distinct on axis 1 and Fall the most distinct on axis 2 (Fig. 2.17). When southern Oregon pitfall totals are ordinated separately by season, a triad effect emerges as the primary determinant of observed community composition (all 3 triads distinct; Fig 2.18). A treatment effect (i.e., old-growth different from thinned and unthinned pole stands) can also be observed at this scale (Fig. 2.19).

An interaction of triad and treatment effects also emerges from the soil community ordinations (Figs. 2.20-2.21). The most distinct soil community in Southern Oregon is the Thompson Creek old-growth. This site is the only one in the study with a prime deciduous element (*Quercus kelloggii* Newb.). The triad (locale) pattern is strongest in the Coast Range and the Cascades (not shown), whereas the treatment effect is stronger in Southern Oregon (p-value = 0.01).

A strong stand treatment effect is displayed in the ordination of the Southern Oregon litter community (Fig. 2.22), overwhelming any triad effect (Fig. 2.23). Old growth is distinct from thinned and unthinned in Southern Oregon; average litter depth is probably the prime driving variable in this case. A similar, less distinct pattern occurs among the Coast Range litter community. The Cascade litter community does not display any treatment effect; instead a triad effect emerges as the primary explanatory factor of the observed community composition.

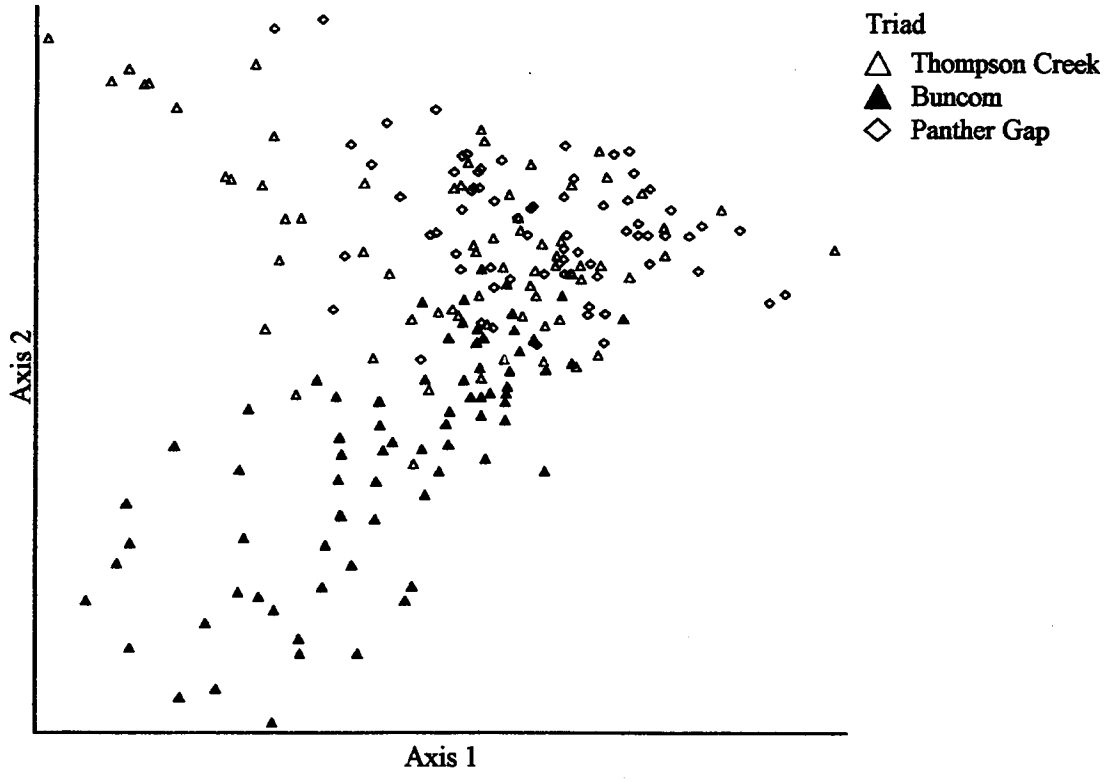


Fig. 2.18 CCA ordination of all SO pitfall samples, log transformed, minus species occurring in less than 5% of all stands, grouped by triad (all three triads distinct).

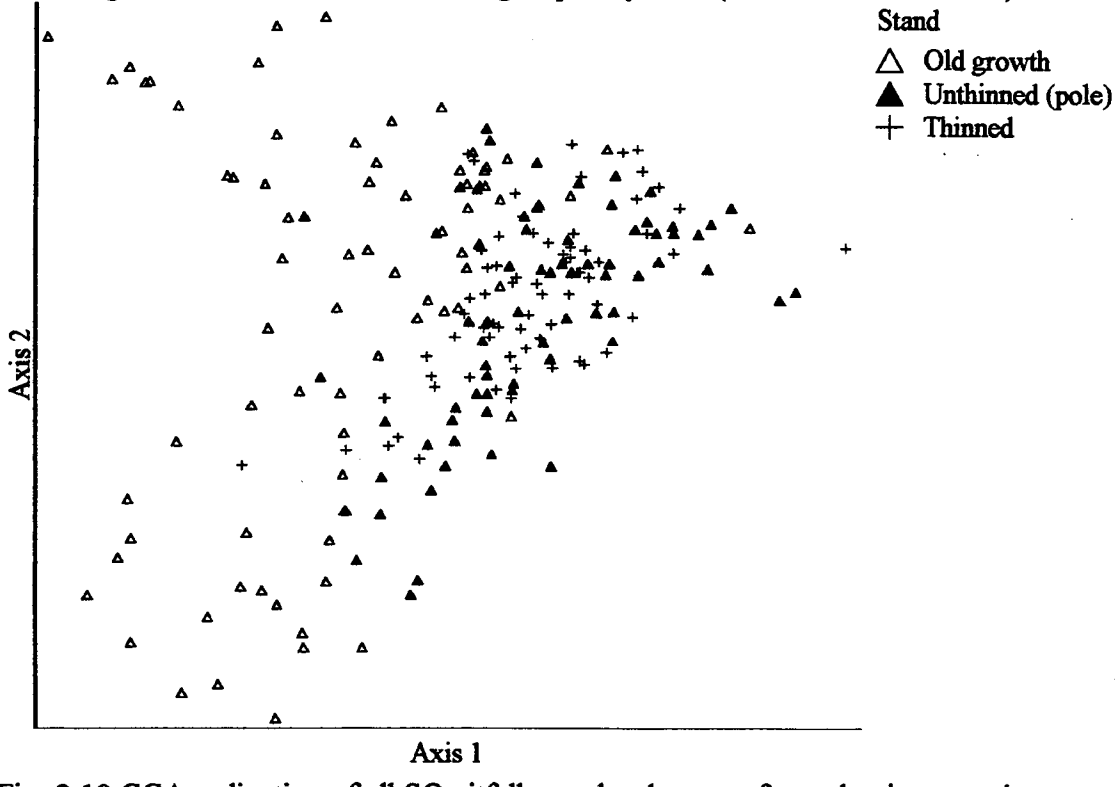


Fig. 2.19 CCA ordination of all SO pitfall samples, log transformed, minus species occurring in less than 5% of all stands, grouped by treatment. (Old-growth separates from unthinned and thinned stands).

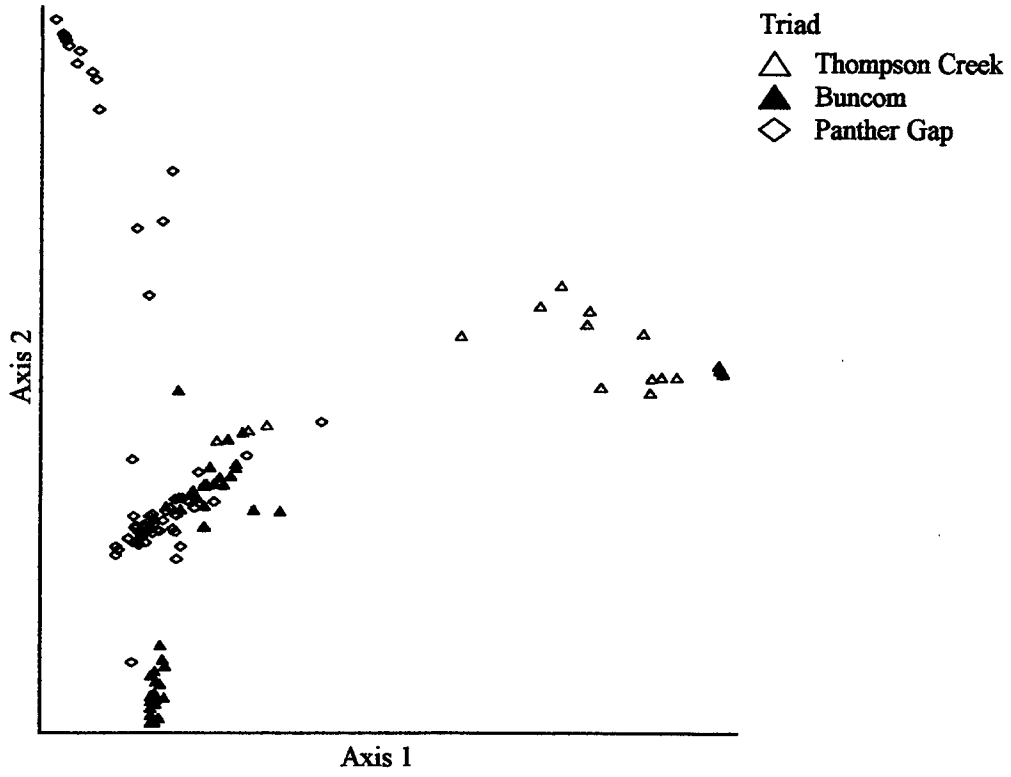


Fig. 2.20 CCA ordination, SO soil samples, log transformed, minus species occurring in less than 5% of samples, grouped by triad. (TC separates on axis 1; B and PG on axis 2)

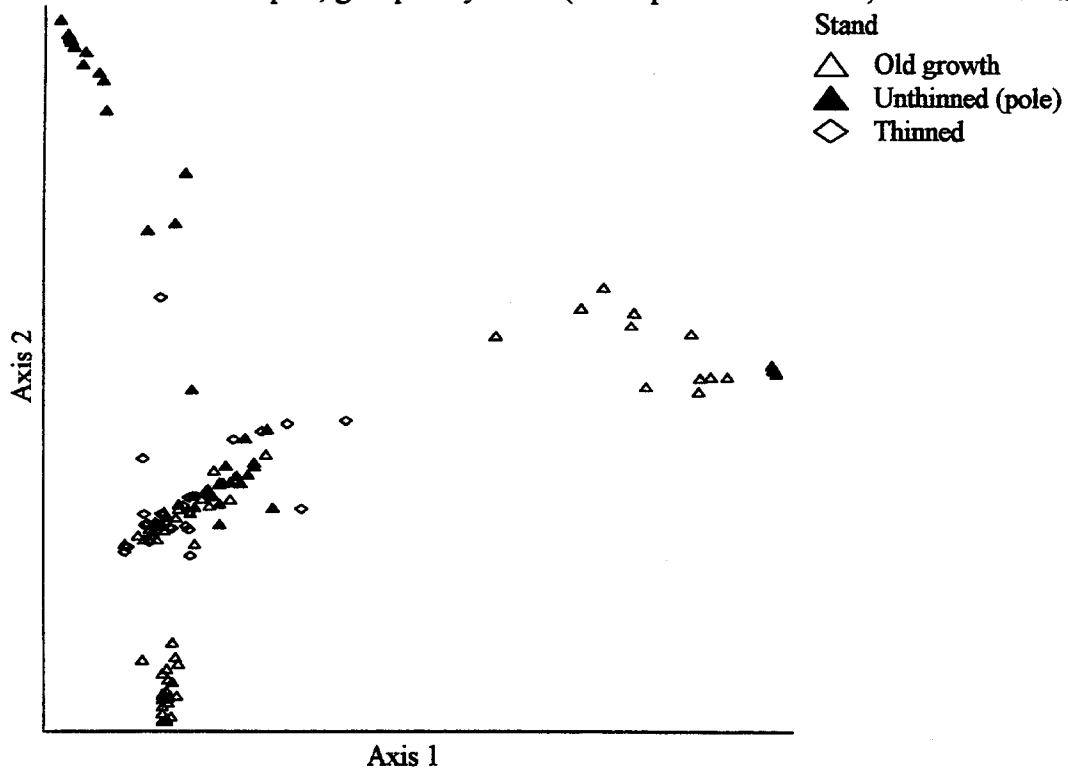


Fig. 2.21 CCA ordination, SO soil samples, log transformed, minus species occurring in less than 5% of all samples, grouped by stand. (OG on axis 1; UT and TH on axis 2)

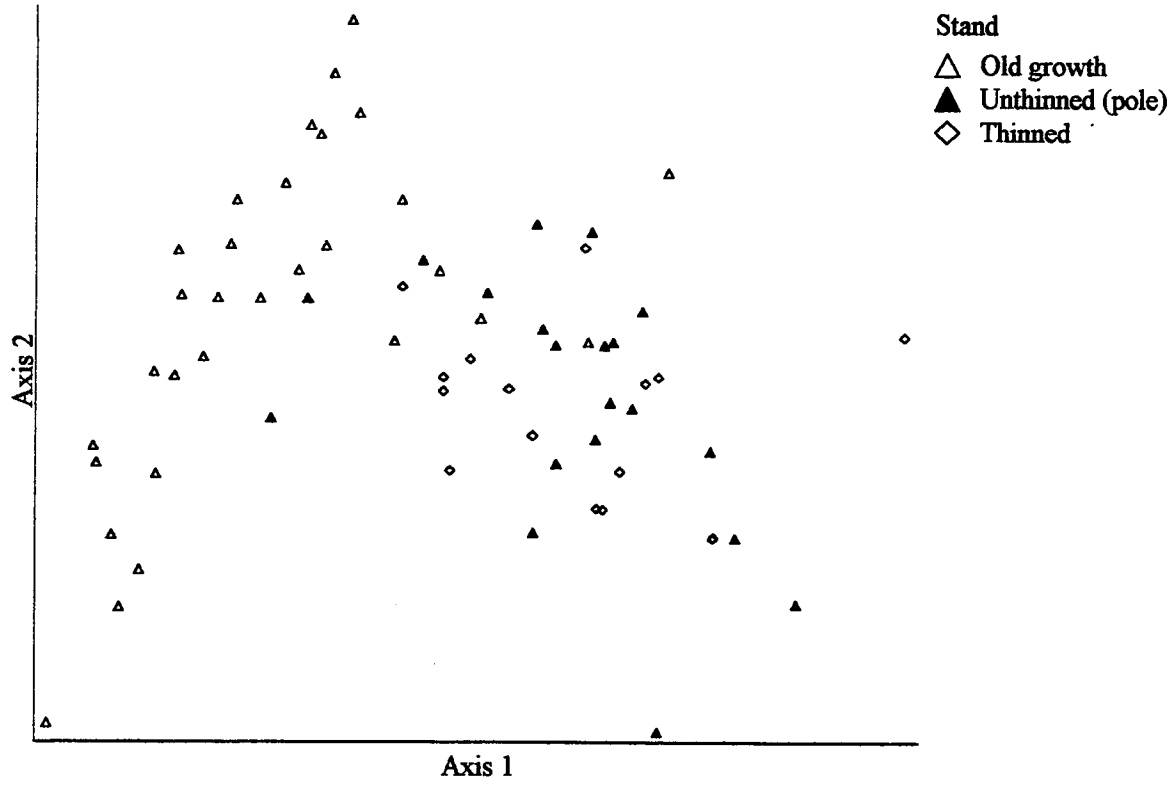


Fig. 2.22 CCA ordination, SO litter samples, log transformed, minus species occurring in less than 5% of all samples, grouped by treatment. (OG separates from UT and TH)

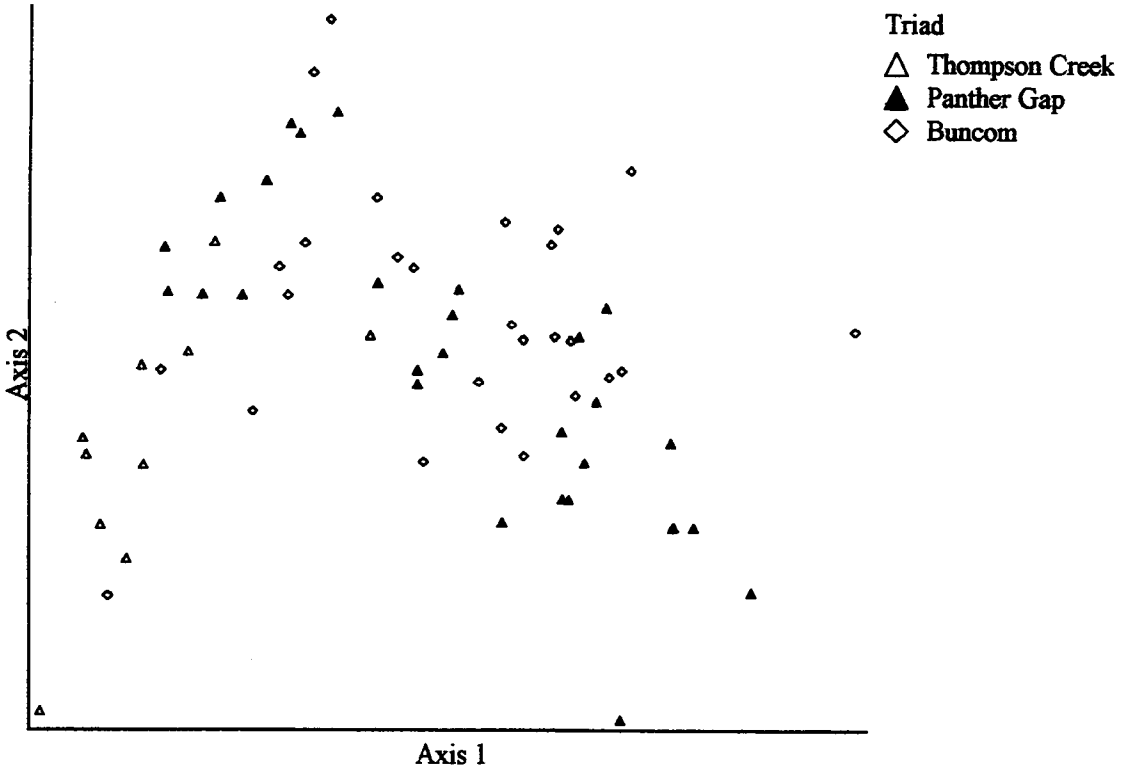


Fig. 2.23 CCA ordination, Southern Oregon litter samples, log transformed, minus species occurring in less than 5% of all samples, grouped by triad. (No distinction by triad)

Arthropod community composition: Intra-triad results

Ordinations of pitfall samples within a single triad showed a strong treatment effect as the explanatory factor of the community composition (Fig. 2.24). All 9 triads yielded similar results, regardless of region (not shown). However, such distinct community composition differences can be unequivocally ascribed to treatment differences only if treatment effects exist at the inter-triad, intra-region level. Even though these sites were established to maximize intra-triad similarity (e.g. vegetation, slope, etc.) (Bailey 1996), the corresponding weakness of a treatment-effect at a inter-triad within-region analysis, implies that more than a simple treatment effect is responsible for divergence of community structure at the intra-triad scale.

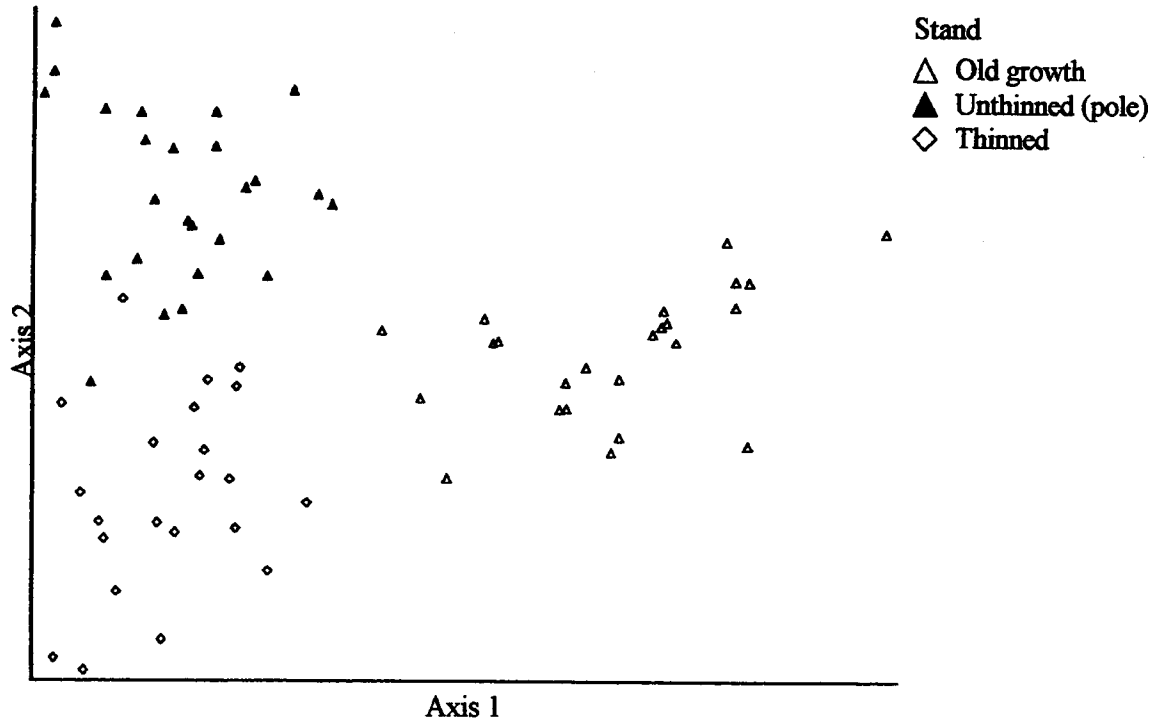


Fig. 2.24 CCA ordination, Triangle Lake Fall pitfall samples, log transformed, minus species occurring in less than 5% of all samples, grouped by treatment. (All treatments are distinct)

Discussion

Neither pitfall macroarthropods, litter meso- and microarthropods nor soil microarthropods revealed a treatment response across all three forested regions of Oregon. It was realistic to expect that such differences would be discovered since a number of environmental factors are known to vary between the three management types.

Coarse woody debris is both a habitat requirement for macroarthropods and a distinct food resource for microinvertebrates and fungi. Older, wider-diameter coarse woody debris is prominent in old-growth (Spies *et al.* 1988; Halpern and Spies 1995). Even in the drier region of Southern Oregon with its more frequent fire cycle (Agee 1993), coarse woody debris is two to four-fold more abundant in old-growth than in mature stands (Table 2.8-2.10). Luoma *et al.* (1991) and O'Dell *et al.* (1992) have documented that mycorrhizal diversity differs significantly between old-growth and younger forests.

The gap structure of old-growth affects surface temperature both in the opening and adjacent canopy cover (Mladenoff 1987; Gray 1995). The staggered canopy of old-growth significantly increases winter condensation throughout the region (Harr 1986). Hence, evapotranspiratory regimes have the potential to be significantly different during the spring and summer seasons, especially since litter depth (insulation and water absorption) in general is deeper in old-growth (Griffiths and Swanson (in press);Topik 1976). Moss-cover and herbaceous or trailing vegetation respond strongly to increased light in forest gaps, providing potentially a far greater resource for herbivorous invertebrates in both old-growth and thinned stands (Halpern and Spies 1995).

Such direct environmental affects of canopy layering, forest gaps, litter and coarse woody debris distinctions would be expected to have indirect effects as well on the arthropod community by altering the species composition of the flora. Different species of plants (especially the distinctions between conifers, sclerophyllous dicots, non-sclerophyllous dicots, ferns and mosses) should alter the palatability spectrum of litter resources, their decay rates and suitability of the resources to both microbial and invertebrate attack (Grier and Logan 1977).

Despite all these sound reasons, thinning the overstory canopy of young Douglas-fir stands in order to increase vegetative structural heterogeneity did not result in a predictable shift in the arthropod community composition at a multi-regional scale of analysis. For pitfall traps in particular, no treatment effect of old-growth, mid-aged pole or thinned stand management upon arthropod community composition was found for the combined totals across all three regions (Fig. 2.13).

Pitfall data from Fall 1995 sampling season was very distinct from the other seasons (Fig 2.10). Since the sampling design did not replicate within seasons, it was not possible to differentiate between the influence of season and annual effect. I think it is most likely that the observed pattern is a repeatable seasonal, instead of yearly, effect, due to cooling temperatures and shifting resource availability. Future research, however, is necessary to confirm this conjecture.

Seasonality was investigated only in pitfall captures. The Mediterranean climate of the Pacific Northwest, with wet, mild winters and hot, dry summers, clearly outweighed any effect of stand management type. This is not surprising, and would be expected to

affect the litter and mineral soil faunas as well (not tested, but note seasonal differences in Moldenke and Fichter 1988, and Moldenke and Thies 1996a, 1996b). Equally significant was the observation that the seasonal effect was most prominent in Southern Oregon, which is characterized by the longest seasonal drought. Samples at the end of the dry season (Fall 1995) were the most distinctive. These climatic patterns and the lack of moisture may explain, in part, why my results confirmed that Southern Oregon had both the lowest population densities (about 20%) and the lowest species richness (about 60%) of soil and litter arthropods

When only pitfall samples from the same season are considered, regional effects outweigh management effects in all sampling categories. However, these results must be qualified, in that the differences between the faunas of Southern Oregon relative to both the Cascades and Coast Range are great; the differences between the Cascades and Coast Range faunas are far less, regardless of sampling methodology. Arthropod community structure is different in Southern Oregon, and this degree of difference is greater than that produced by management types in the less water-stressed forests.

Forest management policies adapted to invertebrate diversity must treat Southern Oregon differently than the central Oregon Coast Range and Cascade Mountains. The panel of entomologists gathered to advise government land managers in the preparation of the Record of Decision, stressed that in their judgment (in the lack of definitive comprehensive documentation) that the Siskiyous and Klamath regions would require distinctive attention since Southern Oregon had:

1) a higher alpha-species richness of arthropods;

2) a higher plant alpha-species diversity, and probably more specialization upon distinct resources, which were themselves by definition more patchy and difficult to colonize;

3) a more stressful climate, and a well-known higher beta-diversity of plants on adjacent contrasting slope faces. (Therefore, higher beta-diversity of arthropods as well, hypothetically.)

4) Far more frequent and severe forest fire-driven disturbance regimes, leading to both a far more fragmented landscape and far more difficult recolonization (especially for flightless arthropods, the majority of the soil fauna).

Contrary to the original hypotheses, the stand treatment type consistently held no pattern when analyzed by the multi-response permutation procedure (MRPP) which yielded a p-value equal to 0.369 on the untransformed data. Region, especially the nine Southern Oregon sites, was consistently found to be the most important explanatory factor across method and season.

Samples from within one region only (i.e. Southern Oregon, Cascades, or Coast Range) revealed an interaction of treatment and locale effects. Treatment effects dominated for the litter fauna; treatment and locale effects were equally strong in soil fauna; and locale effects dominated in the pitfall fauna. (Figs. 2.14-2.16)

The much greater inherent mobility of the pitfall fauna should render localized treatment effects (thinned versus pole stands were always adjacent plots of land) more difficult to detect. High percentages of flightlessness within the soil and litter faunas

should predispose both to local differentiation, but the higher species richness of the litter fauna permits better resolution of differences.

Regardless of region and sampling methodology the old-growth is always the most distinct, with pole and thinned either indistinguishable or partially overlapping. The uniqueness of old-growth follows from the logic presented at the beginning of the Discussion. What comes as a surprise, however, is the weakness of this old-growth effect.

Since all of these old-growth stands represent islands, averaging eighteen acres each, surrounded by extensive regions of forest fire devastation or clear-cutting, they may not be adequate representations of "pre-disturbance" old-growth faunas. This supposition is supported by the findings of Chen *et al.* (1995). They found that edge effects typically extended 30 to >240 m into the forest, affecting air and soil temperatures (during the day temperatures decreased the further the distance from the edge, the reverse was true at night), humidity (increased from the edge), short-wave radiation (decreased from the edge) and wind speed (decreased exponentially from the edge, depending on orientation). The wide-ranging mobility of the pitfall macroarthropod fauna may overwhelm such isolated remnant stands. This issue can only be analyzed within large wilderness preserves, which may have extensive stands of old-growth.

Triad (locale) effects are strongest for Southern Oregon, regardless of sampling methodology. The strength of the triad effects is surprising; sites were geographically very close, with no floristic reasons to suspect a triad effect.

All nine triads show a strong "pseudo-treatment effect" when analysis is only within a triad. At this level a treatment effect is not statistically distinguishable from a sub-

locale effect. Without replication a treatment effect could easily be confused with a location effect; my studies imply that such location effects are liable to be equally important as true treatment effects.

Conclusions

On a multi-regional scale, such as western Oregon, seasonal, then regional and climatic differences, are clearly the strongest determinants of arthropod community composition, far stronger than any management effect or old-growth effect. There are management effects; they are, however, less significant. Within a region, locale differences are often stronger influences upon community composition than management protocols. An exception is in the litter community, where stand management differences overwhelm the locale (triad) effect. The litter community is less mobile than the pitfall community, far more species-rich and more susceptible to alteration than the soil community. These three factors cause the litter community to respond more readily, and for these responses to be more detectable.

These results have a significant bearing on the "old-growth controversy" in the Pacific Northwest. Abstract conceptual characterizations of old-growth (i.e., big trees, multi-canopied, island gaps with ground cover, diverse understory) and young pole stands (dense trunks, little understory or ground cover) would predispose most foresters and ecologists alike to assume that stand-type differences would have major influences on vegetative and invertebrate diversity. Nearly everyone acknowledges that these effects should be greatest on arthropod diversity, since arthropods comprise such a large

percentage of total community species richness (Samways 1994). This study is one of the first to examine arthropod diversity (hundreds of species in unrelated taxonomic groups), and it tells us:

1) Old-growth is really not all that different from other closed-canopy forest stands. Of course it is different, but the differences are outweighed by "relatively minor" geographic placements of as little as a few kilometers.
2) Geographic and geologic heterogeneity are prime determinants of arthropod diversity. It is therefore not a realistic management option to save just a "couple of old-growth stands" in order to preserve biotic diversity and ecosystem function. Stands under multiple management strategies must be thoroughly scattered throughout the forest landscape.
3) The arthropod fauna of Southern Oregon is quite distinct from that of the Coast Range and the Cascades. The distinctiveness of management concerns detailed in the Record of Decision are substantiated. Species diversity is distinct (higher beta-diversity), richness is higher and the decades-long legacy of thinning is more demonstrable.

Chapter 3

Effect of Microhabitat upon Determining Within-stand Arthropod Community Composition and Diversity in Douglas-fir Stands in Southern Oregon.

Stephanie L. Madson

Introduction

It has been postulated that species richness is beneficial or even necessary to maintain ecosystem processes and sustainability (Tilman *et al.* 1996, Kareiva 1996, Wilson 1992, Vitousek and Hooper 1993). This has been successfully demonstrated in only a handful of field studies (Tilman *et al.* 1996, Tilman and Downing 1994) due to the complexity of interactions amongst abiotic and biotic factors within ecosystems. Fewer studies, if any, have shown what is determining diversity, especially in belowground systems. Plant species diversity, species interactions, abiotic factors, nutrient availability, disturbance, stand history and/or forest structure all play large roles (Scheu and Schulz 1996) (Figure 3.1).

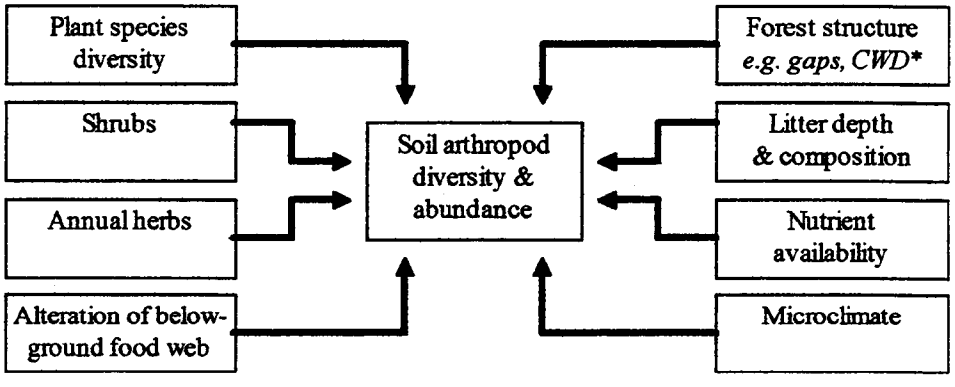


Figure 3.1. Potential drivers of soil arthropod diversity and abundance.
*CWD - coarse woody debris

Belowground terrestrial systems are extremely diverse. It has been estimated that there are at least 8,000 species of soil arthropods on the Andrews Experimental Forest in Oregon (Moldenke personal communication, Beard 1991 as quoted by Wardle and Giller

1996). A majority of these are not even described and there is a dearth of information upon the biology and interactions of belowground species (Coleman and Crossley 1996).

Soil arthropods are important to ecosystem processes and sustainability through their regulation of decomposition, nutrient cycling, and energy flow (Wardle and Giller 1996, Seastedt 1984, Moldenke *et al.* 1994, and Christiansen *et al.* 1989). If managers wish to maintain or rehabilitate ecosystem functions, it is critical to know what factors affect soil arthropods.

The purpose of this study was to examine the correlation between microhabitat variables generally measured by soil microbial ecologists with soil arthropod community composition.

Methods

Study areas

This research was conducted in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests on Bureau of Land Management (BLM) lands in the Siskiyou Range of southwestern Oregon. The entire experimental design was replicated in the Coast Range and Cascades of central Oregon (see Fig. 3.2); only Southern Oregon data will be reported here. Nine sites were selected with the assistance of BLM employees and measured in the spring of 1994. Aerial photos, stand history, current stand management, location, and slope were criteria used to select sites. Three triads were identified in the region. Each triad contained three treatments: an unthinned mid-aged stand, a thinned mid-aged stand,

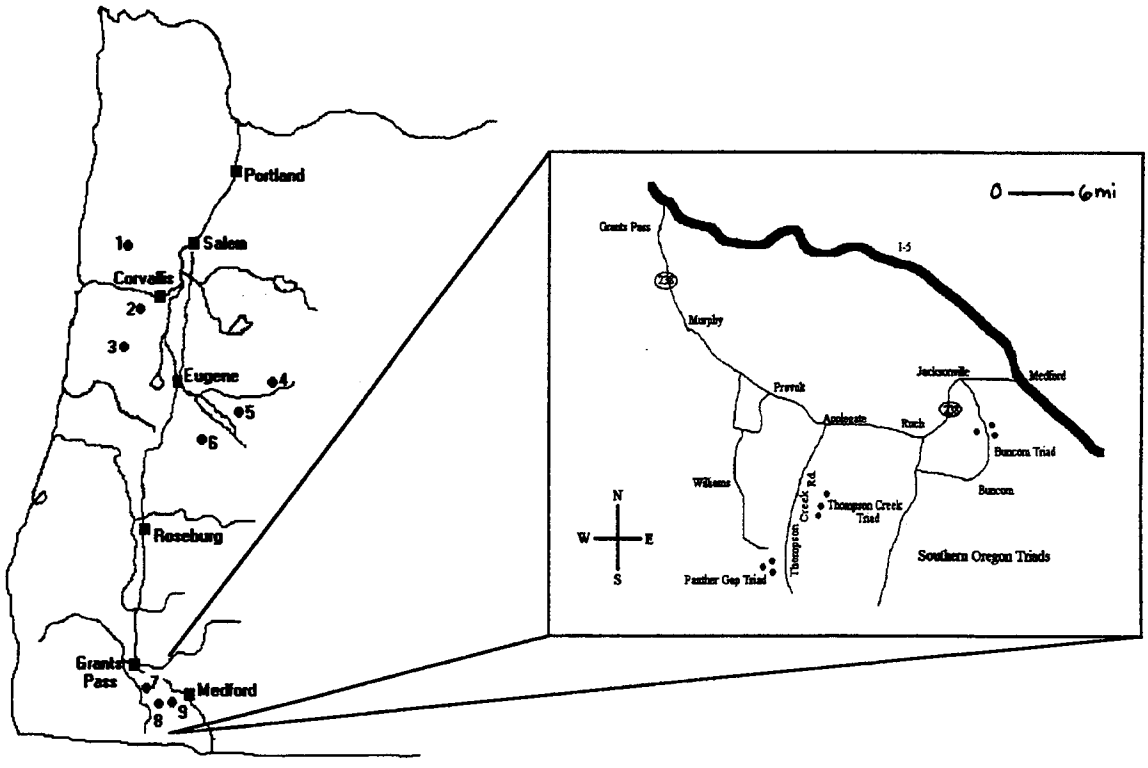


Fig. 3.2. Triad locations in Western Oregon.
Coast Range: 1- Sand Creek, 2- Mary's Peak, 3- Triangle Lake
Cascades: 4- H.J. Andrews, 5- Marten Ridge, 6- Eagles Rest
Southern OR: 7- Panther Gap, 8- Thompson Creek, 9- Buncom

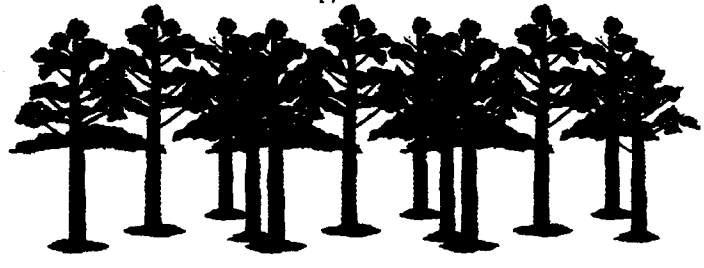
and an old-growth stand. Stands within a triad were located as closely as possible to each other, preferably with similar slopes and aspects.

Precipitation was primarily in the form of rain and temperatures tended to be mild at all sites. Weather and temperature data were taken from the Western Regional Climate Center web page (McCurdy 1997). Total annual precipitation in Southern Oregon averages 79 cm and total annual snowfall averages 10.7 cm. The annual high temperature for Southern Oregon is 68.5°F and the annual low is 40.8°F. Most sites were within the Western Hemlock Zone (Franklin and Dyrness 1984 as quoted by Bailey 1996) where

hemlock (*Tsuga heterophylla* (Raf.) Sarg.) is considered climax. The Thompson Creek triad was within, or near transition into, the Douglas-fir Zone (Franklin and Dryness 1984 as quoted by Bailey 1996), with Douglas-fir as the climax species.

Old-growth stands were defined as over 100 years old, with multi-layered canopies, light gaps and minimal logging disturbance (Fig. 3.3). Mid-aged (pole) stands had reseeded naturally following either harvest or fire in the late 1800's and early

Old growth stand



Mid-aged pole stand

Unevenly thinned stand

Old-growth:

Multi-storied canopy
Gaps
Over 100 years old

Unthinned (pole):

Reseeded naturally after disturbance
Single canopy layer
No gaps
40-50 years old

Thinned stand:

Pole stand that was thinned 10-15 years ago
Multi-storied canopy
Gaps
Mimics old-growth.

Figure 3.3. Schematic of management

1900's (Bailey 1996). Mid-aged stands were between 50 to 90 years old, dominated by one-age cohort, with a single canopy layer and no light gaps. Thinning was conducted between 1971 and 1985, depending on the stand. Thinnings were moderately heavy (20 to 51% merchantable volume removal, respectively) (Bailey 1996), resulting in development of an understory shrub layer. No additional treatments (e.g. fertilization) were recorded in either the thinned or unthinned stands (Bailey 1996). For a further description of stand characteristics, see Chapter 2 or Bailey (1996).

Field and laboratory methods

All samples were taken along a 250 meter transect line established within each stand. Transects were established using a compass to walk a line across a stand, running perpendicular to the slope. Ravines and streambeds were avoided. A minimum distance of 10m from the stand edge was maintained. Occasionally, it was not possible to meet these criteria and establish a single line. In these cases, the line was interrupted and two parallel segments (at least 20 m apart) were set. There were 25 sampling points, 10 meters apart, per transect. Average stand size was 18 acres.

Soil Cores

Twenty-five soil cores were taken to sample soil mesofauna (e.g. Acari and Collembola spp.). Samples were taken 10 meters apart, at every other sampling point and alternating with the pitfall traps. The litter layer was removed and a 7.5 cm. diameter core of soil, 10 cm. in depth, was taken with a hand trowel. Cores were placed in sealed plastic bags and then into 2-5° C cold storage. Arthropods were subsequently heat extracted

using Tullgren funnels. See Winter and Voroney (1993) for an in-depth discussion of this method. The soil was sampled during June of 1994.

Microhabitat variables

Microhabitat variables were measured for each sample point along the transect. Microhabitat variables were measured either by myself or by Dr. Robert Griffiths and Shirley King in a related soil study.

Soil variables measured were field respiration, lab respiration, substrate-induced respiration, water-amended respiration, bulk-density, p-moisture, pH, soil organic matter, extractable ammonium, net mineralizable nitrogen, dissolved organic carbon, and denitrification (Table 3.1) (see Griffiths *et al.* a, b, in preparation, for precise discussion of methods).

Data analysis

Ordinations were used to examine the overall pattern of arthropod communities within southern Oregon. The main matrix consisted of count data of species occurrences within a sample core. Potential driving variables of community composition and diversity were studied by correlation of community patterns with microbial variables (Griffiths *et al.* a, b, in preparation; Bailey 1996). Microhabitat descriptors were overlaid on the stand arthropod community data to aid in recognizing patterns and to suggest potential determinants of those patterns.

Data were analyzed using the computer statistical package PCORD (McCune and Mefford 1995). Initially, a row and column summary was run to yield descriptive statistics

on the main matrix (Madson, in prep, Chapter 1,Table 2.12). Beta diversity was greater than 2.0, suggesting the use of Sorensen's index over an Euclidean distance measure.

Elevated skewness and beta diversity, suggesting a mild zero-truncation problem, indicated the necessity for transformation. Initial ordinations were run on untransformed data in order to determine the effects of subsequent transformations upon the matrix. A variety of ordination methods and transformations, including Bray-Curtis (B-C) ordination, non-metric multi-dimensional scaling (NMS), detrended correspondence analysis (DCA), canonical correspondence analysis (CCA), hierarchical clustering and multi-response permutation procedures, were initially run to become familiar with the response of this data set to different analysis tools and to aid in determining the most appropriate method (Madson, in prep, Chapter 1, Figs. 2.4-2.11). All four ordination methods yielded similar results in analyzing these data sets, with CCA providing the greatest clarity and DCA providing the least clarity.

The data sets were comprised of non-normal, community data, with high skewness and beta diversity. The matrices were count data of relative abundance of arthropods collected. Prior to all ordination methods, rare species, defined as occurring in 5% or less of the sample units, were deleted and data were transformed. The Beals smoothing was most effective with the Bray-Curtis ordination method, whereas the log-transformation was the most effective in enhancing patterns with the other three methods. As a result, CCA ordinations on log-transformed data were used to analyze the data sets in this study, since these methods yielded the ordinations with the greatest clarity. CCA also has the advantage of being the ordination technique used most often in the literature.

Table 3.1 Sample environmental matrix used in ordination analysis (SO litter samples), per PCORD specifications.
Values represent Southern Oregon stand-level averages (zeroes represent empty or missing data points). Rows are individual stands: Thompson Creek (TC), Buncom (BU), Panther Gap (PG), old-growth (O or OG), unthinned pole (P), thinned pole (T). Columns are environmental and microbial variables: stand age (Age), trees per acre (TPA), basal area (BA), percent of basal area comprised of hardwood species (HWD), total leaf area index (TLAI), total coarse woody debris (TCWD), density of tall shrubs per acre (S/A), percent low or "small" shrub cover (SSC), seedling density per acre (#SD) (Bailey 1996); litter depth (mm) (LITTER), soil bulk density (Bulk-den), soil pH (pH), fraction dry weight (FDW), percent moisture (p_moist), soil organic matter (SOM), extractable ammonium (Extr_Amm), net mineralizable nitrogen (NetNmin), dissolved organic carbon (DOC), denitrification (Dentit.), field respiration (Total CO2), lab respiration (LabResp), water-amended respiration (H2Oresp), substrate-induced respiration (SIR), soil temperature (Temp) (Griffiths *et al.* in prep. a, b). Variables are either quantitative (Q) or categorical (C).

9 Stands
33 Environs

	Q TC	Q BU	Q PG	Q OG	Q P	Q T	C Triad	C Stand	Q Age	Q TPA	Q BA	Q HWD
TCO	1	0	0	1	0	0	1	1	110	30	144	0
TCP	1	0	0	0	1	0	1	2	90	154	112	0
TCT	1	0	0	0	0	1	1	3	110	61	164	0
BUO	0	1	0	1	0	0	2	1	160	35	168.9	0
BUP	0	1	0	0	1	0	2	2	160	74	153	0
BUT	0	1	0	0	0	1	2	3	120	64	107	0
PGO	0	0	1	1	0	0	3	1	140	89	176	5
PGP	0	0	1	0	1	0	3	2	120	156	118	8
PGT	0	0	1	0	0	1	3	3	120	99	111	3

Table 3.1 con't.

	Q TLAI	Q TCWD	Q S/A	Q SSC	Q SD	Q LITTER	Q Bulk_den	Q pH	Q FDW	Q p_moist	Q SOM	Q Extr_Amm
TCO	3.8	4714	1199	38	339	40.4	0.781	6.171	0.870	15.009	14.059	0
TCP	3.7	747	81	0	0	14.0	0.944	0	0.957	4.581	9.180	3.650
TCT	4.1	0	114	2	636	33.3	0	6.384	0.910	9.973	13.564	6.468
BUO	3.4	4488	1256	13	295	34.5	0.767	6.222	0.821	30.893	15.139	2.643
BUP	3.5	3606	132	0	41	22.0	0.831	6.067	0.928	7.825	13.724	2.714
BUT	2.5	1936	397	4	1231	17.8	0.711	6.224	0.950	5.264	8.388	2.428
PGO	4	5960	746	17	224	27.6	0.852	6.284	0.904	10.769	13.477	0
PGP	3.6	902	585	14	97	25.0	0.980	6.195	0.943	6.069	12.528	2.833
PGT	2.6	3938	1205	11	1129	22.4	0.672	6.279	0.938	6.641	14.644	4.599

	Q NetNmin	Q DOC	Q Dentit.	Q TotalCO2	Q LabResp	Q H2Oresp	Q SIR	Q Temp
TCO	79.729	0.768	1.187	0.997	0.060	0.073	0.028	12.1
TCP	133.312	0	3.590	0.445	0.028	0.101	0.033	11.3
TCT	152.562	0.658	1.389	0.830	0.041	0.115	0.042	13.5
BUO	88.216	0.603	3.520	0.974	0.030	0.104	0.005	11.0
BUP	60.740	0.818	0	0.358	0.055	0.121	0.021	9.8
BUT	47.306	0.681	0.281	1.071	0.025	0.181	0.039	14.7
PGO	89.603	0.483	1.196	0.624	0.036	0.117	0.005	12.4
PGP	66.710	0	0.240	0.662	0.033	0.321	0	15.8
PGT	71.044	1.121	1.609	0.429	0.056	0.230	0.046	14.6

All CCA ordinations discussed in this paper used Hill's scaling to rescale site scores. Optimization of site scores (alpha=0) was the option chosen for scaling of the ordination. "Sample unit scores derived from taxa" was the option chosen for graphing. Monte Carlo tests, with 100 iterations, were run with each ordination to test if no relationship existed between matrices.

Analytical details for the Buncom old-growth are presented to document the method of analysis, strength of correlation response, identification of outliers, and statistical response to outlier removal. I will present only the detailed graphical results from the Buncom (Southern Oregon) old-growth to demonstrate a representative pattern of analysis.

Results

Potential variables determining community composition and diversity were studied by correlation of community patterns with stand structural variables measured in both this study and two related studies (Griffiths *et al.* a, b, in preparation; Bailey 1996). The environmental matrix was formed of soil processes, vegetation, stand structure and stand histories. These environmental characters were overlaid on the stand arthropod community data to aid in recognizing patterns and to suggest potential determinants of those patterns.

Ordinations of soil arthropod assemblages generated neither distinctive nor repetitive patterns of the stand communities, such as either more than a single cloud of sample points or a clustering of adjacent samples within the single cloud of sampling

points (Fig. 3.4). Figure 3.5 shows the change in distribution of sample points after two outliers were removed (su6 and su8). Ordinations indicated that the combined soil fauna community considered all individual stands, regardless of triad, relatively homogenous.

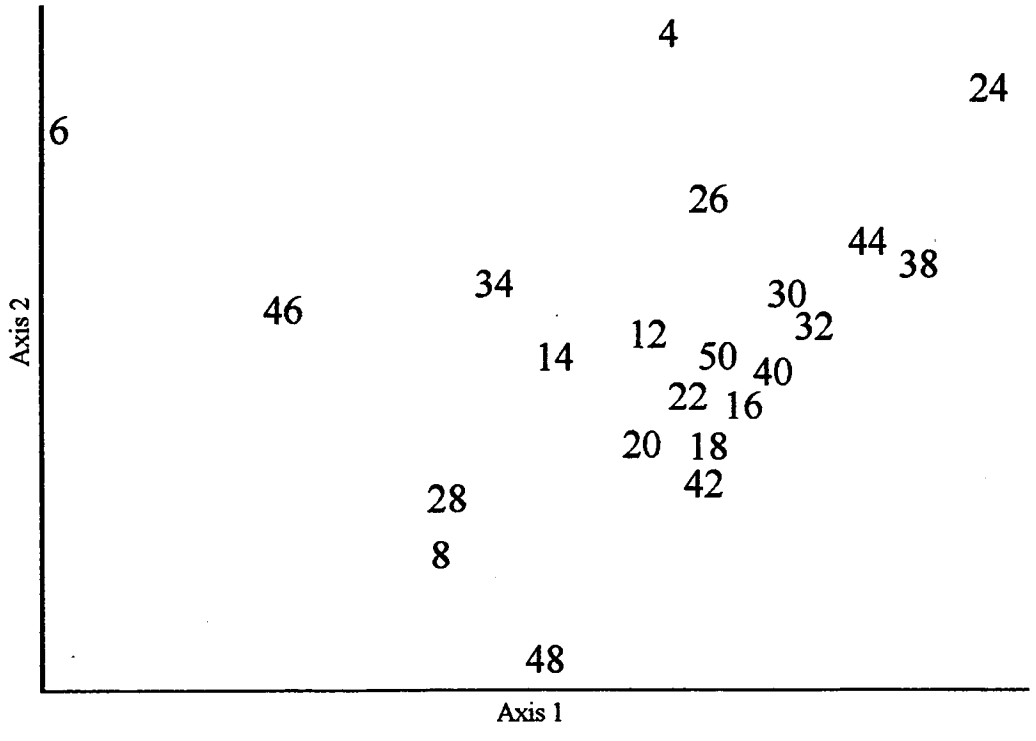


Fig. 3.4 CCA ordination, Buncom old-growth soil arthropod samples, log-transformed, minus species occurring in less than 5% of all samples, grouped by sample unit. (Single cloud with 1-4 outliers; no within-cloud apparent clustering of more than two sequential samples)

Overlaying the microhabitat variables upon the pattern of sample units distinguished one or two outliers from the main cluster of data points (N=25) for any one stand. Microhabitat variables also did not yield clusters of points within the stand that corresponded with an arthropod community composition, for instance a clustered arthropod community consistently corresponding with moister than usual sites. No one

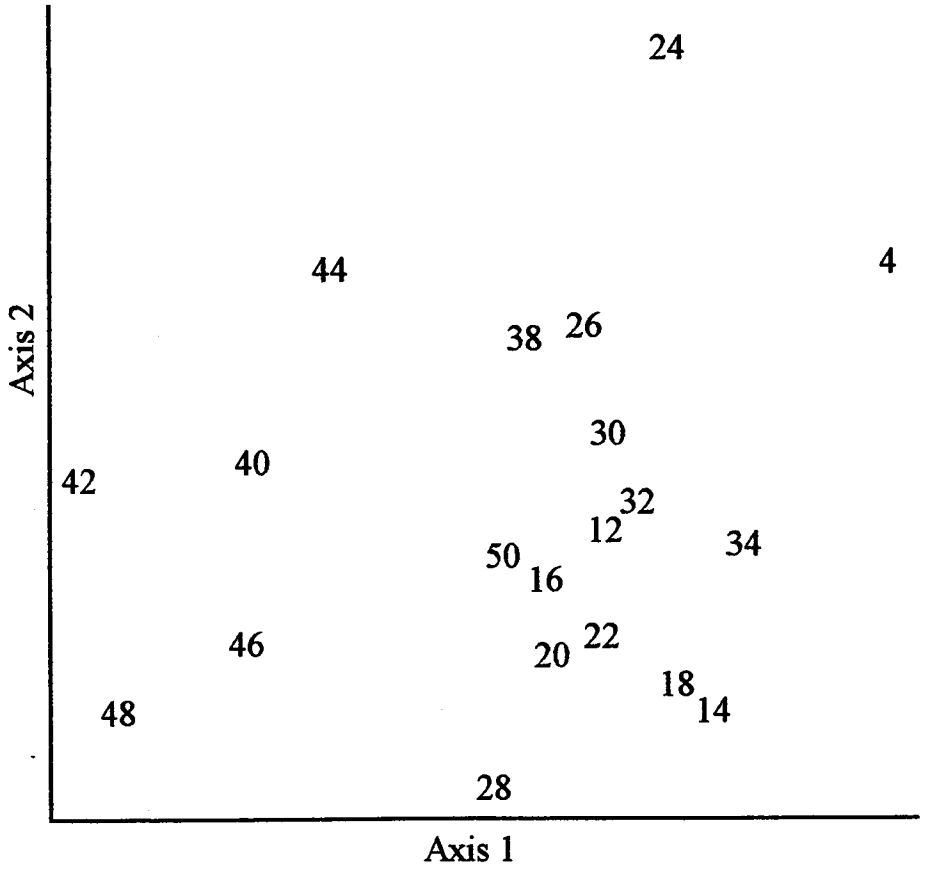


Fig. 3.5 CCA ordination, Buncom old-growth soil arthropod samples, log-transformed, minus species occurring in less than 5% of all samples, grouped by sample unit, minus outliers 6 and 8. (Single cloud with 1-2 outliers; within-cloud apparent clustering sample units 38-50)

microhabitat variable or grouping of variables associated with the distribution of the data points in space (Figs. 3.6-3.19). Repeated ordinations at the other sites indicated that the arthropod distributions were unique at this scale of analysis (Tables 3.2-3.4).

Arthropod community structure at Thompson Creek old-growth, after the removal of outliers, reveals the tightest correlation with field respiration (r=0.4), water-amended respiration (r=0.4), substrate-induced respiration (r=-0.4, 0.3), litter depth (r=-0.3)and soil temperature (r=0.3). Outlier points were characterized by few species or high numbers of

individuals (Table 3.2). None of the microhabitat variables exhibited more than a weak slope and low r-value at Thompson Creek old-growth.

Table 3.2 Slope and R-values (CCA) for Thompson Creek old-growth (Southern Oregon) microhabitat variables, minus outliers (sample units (su's) 34, 24, 8, 10, 16**).

	Thompson Creek old-growth			
	Axis 1		Axis 2	
Variable	slope	r-value	slope	r-value
Dist. From start of transect	-low	-0.232	-low	-0.216
Field respiration	+low	0.035	+low	0.359
Lab respiration	+low	0.270	-low	-0.182
H_2O respiration	+low	0.386	-low	-0.141
SIR	-low	-0.350	+low	0.343
Litter depth (mm)	-low	-0.361	+low	0.167
Soil temperature	+low	0.306	+low	0.080
Bulk density	N/A	N/A	N/A	N/A
pH	+low	0.020	+low	0.025
% Moisture	-low	-0.227	-low	0.222
Soil organic matter	-low	-0.046	-low	-0.045
Extractable ammonium	N/A	N/A	N/A	N/A
Net mineralizable N	-low	-0.134	-low	-0.091
Dissolved organic carbon	-low	-0.094	-low	-0.023
Denitrification	-low	-0.243	-low	-0.146
Eigenvalue	0.286		0.262	
P-value	0.920		0.600	

** Outliers were characterized by either a couple of species (su's 34, 10, 16) or by high numbers of individuals of some species (su's 8, 24).

The unthinned pole stand, at Buncom, revealed the tightest correlation on axis 1 with field respiration (r=0.5) and percent moisture (0.5), with strong, positive slopes after the removal of outliers (Table 3.3). Outliers were characterized similarly to those in Thompson Creek old-growth. Extractable ammonium (r=0.3), litter depth (r=-0.4), soil

Table 3.3 Slope and R-values (CCA) for Buncom triad (Southern Oregon) microhabitat variables.

	Buncom old-growth				Buncom unthinned (pole) (-su's 2, 6, 22, 28)			
	Axis 1		Axis 2		Axis 1		Axis 2	
Variable	slope	r-value	slope	r-value	slope	r-value	slope	r-value
Dist. from start of transect	-high	*-0.749	-low	-0.058	+low	0.358	+low	0.029
Field respiration	+low	0.049	+high	*0.485	+high	*0.540	-low	-0.277
Lab respiration	+high	*0.462	-low	-0.129	-low	-0.278	-low	-0.297
Water-amended respiration	+high	*0.598	-low	-0.158	-low	-0.131	+low	0.140
Substrate-induced respiration	+low	0.235	+low	0.097	+low	0.204	-low	-0.166
Litter depth (mm)	-low	-0.220	+low	0.047	+low	0.071	-low	-0.387
Soil temperature	+low	0.086	-low	-0.371	-low	-0.095	+low	0.319
Bulk density	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
pH	+low	0.084	+low	0.101	+low	0.071	+low	0.073
% Moisture	-high	*-0.746	-low	-0.086	+high	*0.488	-low	-0.223
Soil organic matter	+low	0.023	+low	0.061	+low	0.209	-low	-0.192
Extractable ammonium	+low	0.129	+low	0.298	+low	0.318	+low	0.147
Net mineralizable nitrogen	+high	*0.726	+low	0.244	+low	0.252	+low	0.072
Dissolved organic carbon	-high	*-0.540	-low	-0.138	+low	0.081	-low	-0.272
Denitrification	+low	0.353	+low	0.177	+low	0.055	-low	-0.164
Eigenvalue	0.201		0.175		0.290		0.202	
P-value	0.10		0.19		0.83		0.85	

* Indicates strongest slope and high r-value (r>0.4).

** Outliers characterized by rare species or high numbers of individuals, no species, or only a few species.

Table 3.4 Slope and R-values (CCA) for Panther Gap triad (Southern Oregon) microhabitat variables.

	Panther Gap old-growth (-su16)**				Panther Gap unthinned (pole)(-su4)				Panther Gap (thinned)			
	Axis 1		Axis 2		Axis 1		Axis 2		Axis 1		Axis 2	
Variable	slope	r-value	slope	r-value	slope	r-value	slope	r-value	slope	r-value	slope	r-value
Dist. start of transect	-low	-0.088	+low	0.030	+low	0.050	+low	0.045	-low	-0.063	+high	*0.475
Field respiration	+low	0.400	-low	-0.192	+low	0.080	-low	-0.393	-low	-0.115	-low	-0.110
Lab respiration	-low	-0.023	-low	-0.272	+low	0.291	-low	-0.238	+low	0.149	+low	0.038
H_2O respiration	-low	-0.033	-low	-0.150	-low	-0.122	+low	0.022	+low	0.150	-low	-0.017
SIR	+low	0.178	-low	-0.373	+low	0.160	-low	-0.223	+low	0.135	+low	0.054
Litter depth (mm)	-low	-0.124	-low	-0.077	-low	-0.275	-low	-0.117	+low	0.189	+low	0.226
Soil temperature	-low	-0.176	+low	0.105	+low	0.286	+low	0.276	-low	-0.001	-low	-0.397
Bulk density	N/A	N/A	N/A	N/A	-low	-0.059	-low	-0.218	N/A	N/A	N/A	N/A
pH	-low	-0.085	-high	*-0.446	+low	0.073	+low	0.177	+low	0.035	-low	-0.067
% Moisture	-low	-0.303	+low	0.134	-low	-0.277	-low	-0.133	+low	0.133	+low	0.096
Soil organic matter	-low	-0.271	zero	0.000	+low	0.033	-low	-0.156	-low	-0.022	+low	0.104
Extractable ammonium	-high	*-0.591	-high	*0.454	+low	0.128	-low	-0.102	+low	0.276	-low	-0.214
Net mineralizable N	-low	-0.351	+low	0.195	+low	0.187	-low	-0.055	+low	0.077	+low	0.278
Dissolved organic carbon	-low	-0.178	-low	-0.189	+high	*0.460	+low	0.261	-low	-0.099	+low	0.163
Denitrification	-high	*-0.518	+low	0.219	+low	0.060	+low	0.072	-low	-0.040	-low	-0.046
Eigenvalue	0.339		0.293		0.487		0.327		0.436		0.264	
P-value	0.800		0.120		0.200		0.270		0.060		0.960	

* Indicates strongest slope and high r-value (r>0.4).

** Outliers characterized by rare species or high numbers of individuals (PGO16), no species (PGP4, PGT6, PGT16, PGT18), only a few species (PGT20).

temperature (r=0.3) and the distance from the start of the transect (r=0.4) were all weakly correlated with the community pattern.

At Panther Gap the highest r-values were associated with: old-growth-denitrification (r=-0.5), extractable ammonium (r=-0.6, r=0.5), field respiration (r=0.4) and pH (r=-0.4); pole- substrate-induced respiration, lab respiration, dissolved organic

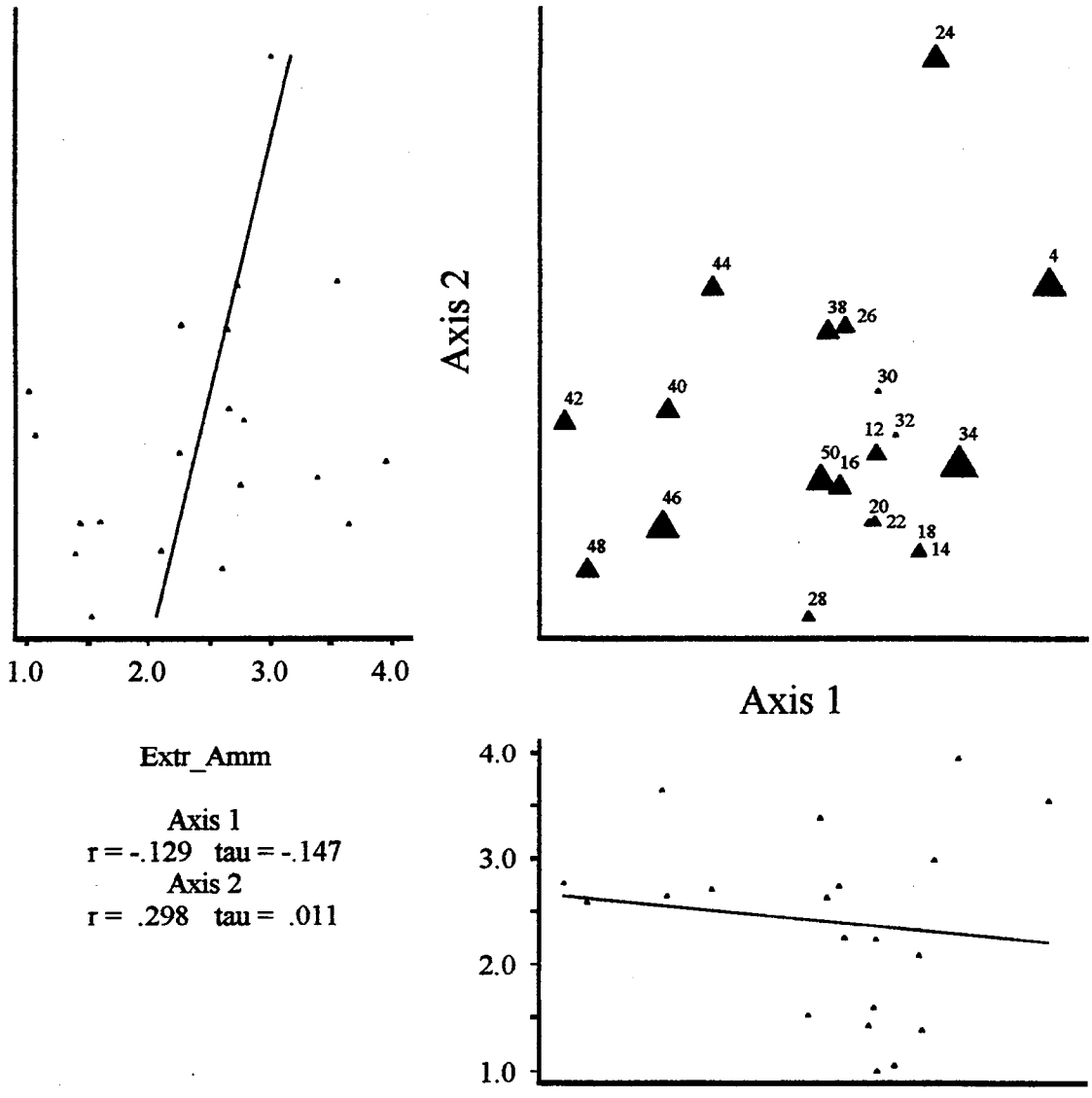


Fig. 3.6 CCA ordination, Buncom old-growth soil samples, log transformed, less 5%, removal of outliers su6 and su 8, correlation with extractable ammonium values. (Random noise on axis 1; weak positive correlation (r= 0.3) on axis 2, outlier su24)

carbon (r=0.5) and field respiration (r=-0.4); thinned- soil temperature (r=0.4) and distance from start of transect (r=0.5) (Table 3.4). Of these, all had high slopes and r-values.

Nitrogen was measured as both extractable ammonium and net mineralizable nitrogen. Figure 3.6 reveals that site su4 and su34, as well as outlier su8, had the highest values of extractable ammonium and that sites su30 and su32 (juxtaposed both by

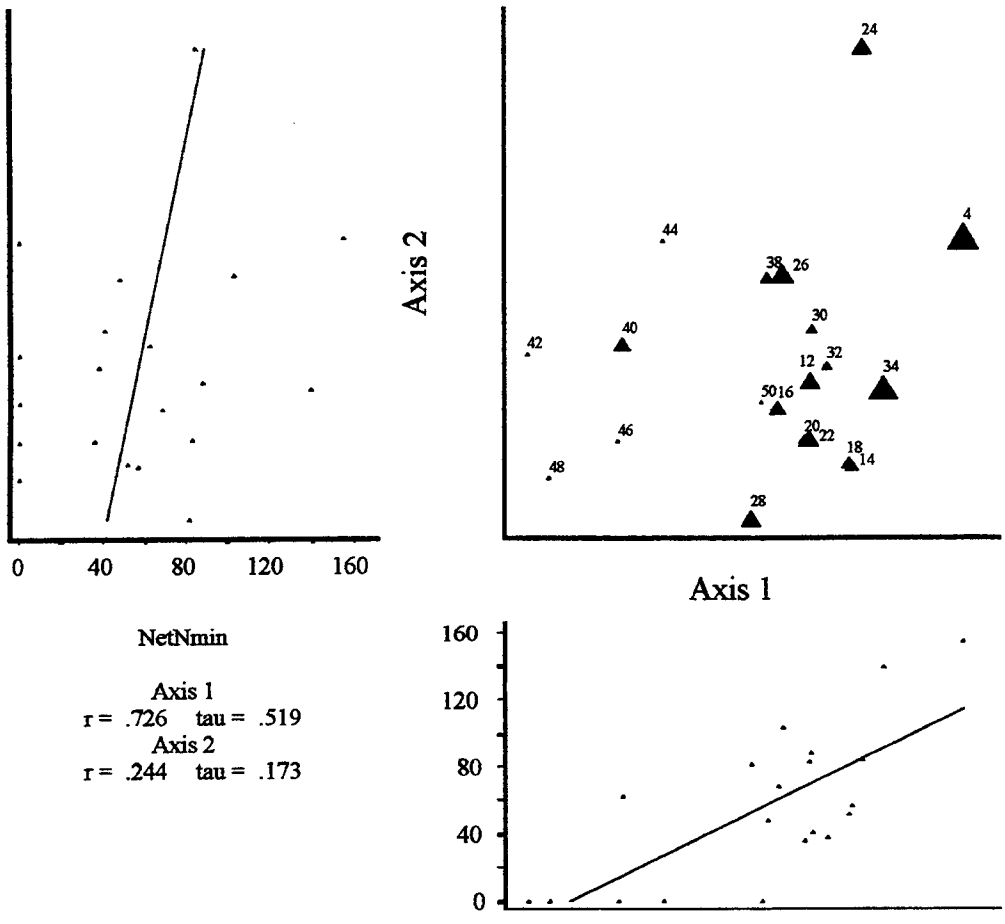


Fig. 3.7 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, correlation with net mineralizable nitrogen. (After removal of outliers su6 and su8, strong slope on axis 1 (r=0.7), due however, to missing values at end of transect; weak slope on axis 2 (r=0.2))

ordination and physical placement) had the lowest. There is a weak negative correlation with the arthropod community (r=-0.3) on the second axis, but no relation at all on the first axis; both axes were significantly impacted by the outlier su8. Figure 3.7 reveals that su4 and su34 are high-value points once again and su42-50 are outliers (due to missing data for these points); without these samples there is a negative correlation (with a weak r-value) between mineralizable nitrogen and the arthropod community.

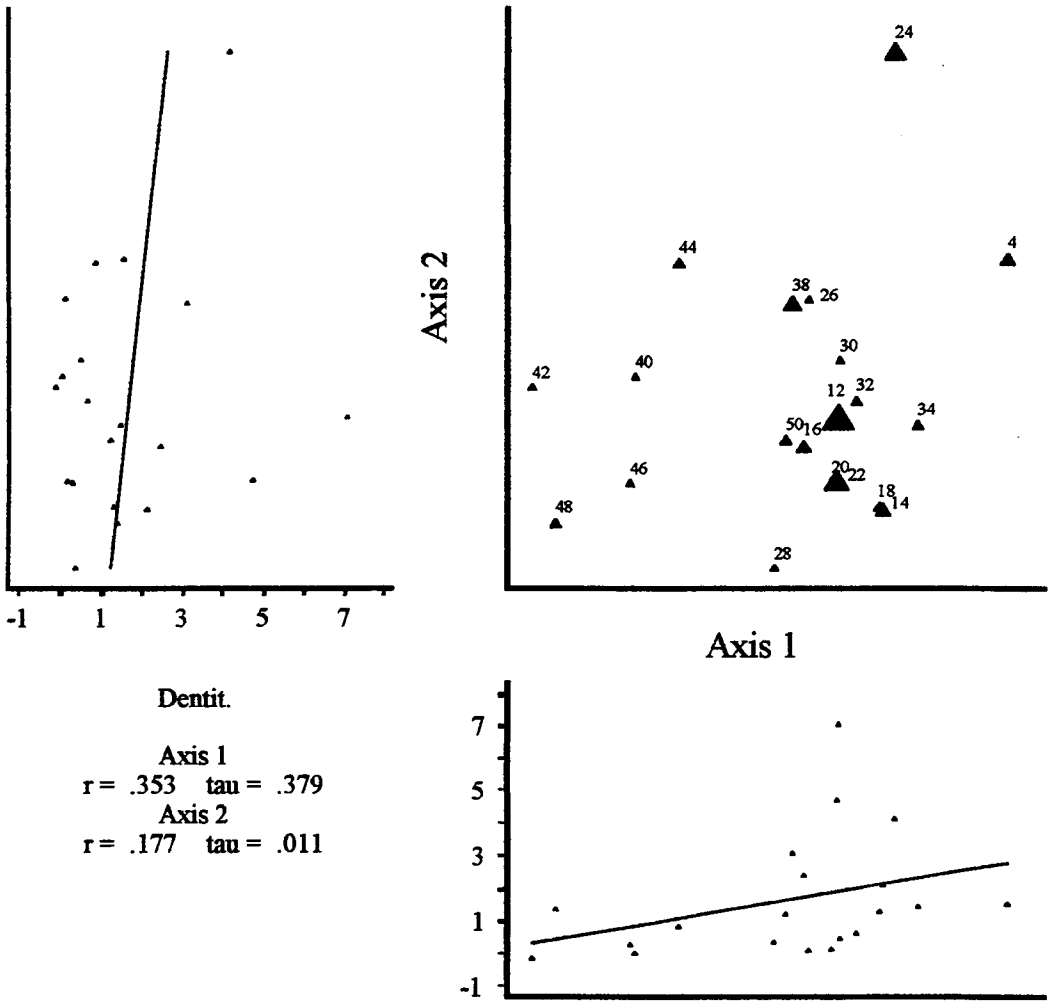


Fig. 3.8 CCA ordination, Buncom old-growth soil samples, log transformed, minus species that occur in less than 5% of all samples, correlated to denitrification values. (Denitrification values minus outliers su6 and su8; weak positive correlation on axis 1)

Figure 3.8 examines the correlation between arthropod fauna and denitrification. After outliers su6 and su8 are removed, there is a weak positive correlation on axis 1 (r=0.4). No discernible pattern emerges on axis 2.

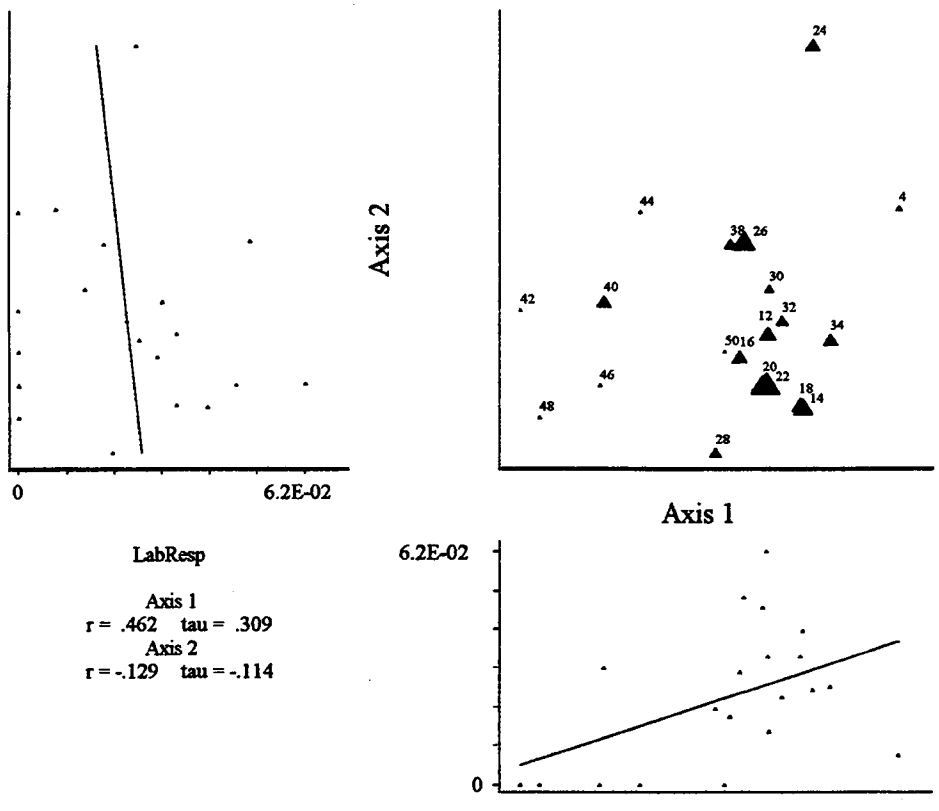


Fig. 3.9 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, minus su6 and su8, correlation with lab respiration values. (su42-50 are missing values, exterting a strong influence on axis 1; no pattern on axis 2)

Soil respiration was assessed in several different ways. Figure 3.9 reveals five outliers due to missing lab respiration values (su42, su44, su46, su48, su50). Removing these data points from the matrix would most likely reveal a weak positive correlation on axis 1. Field respiration (Figure 3.10) reveals a positive correlation with the

arthropod community, with a high r-value (r= 0.5) on axis 2. This measure includes respiration from litter, roots, coarse woody debris and arthropods, in contrast to the data in Figure 3.9.

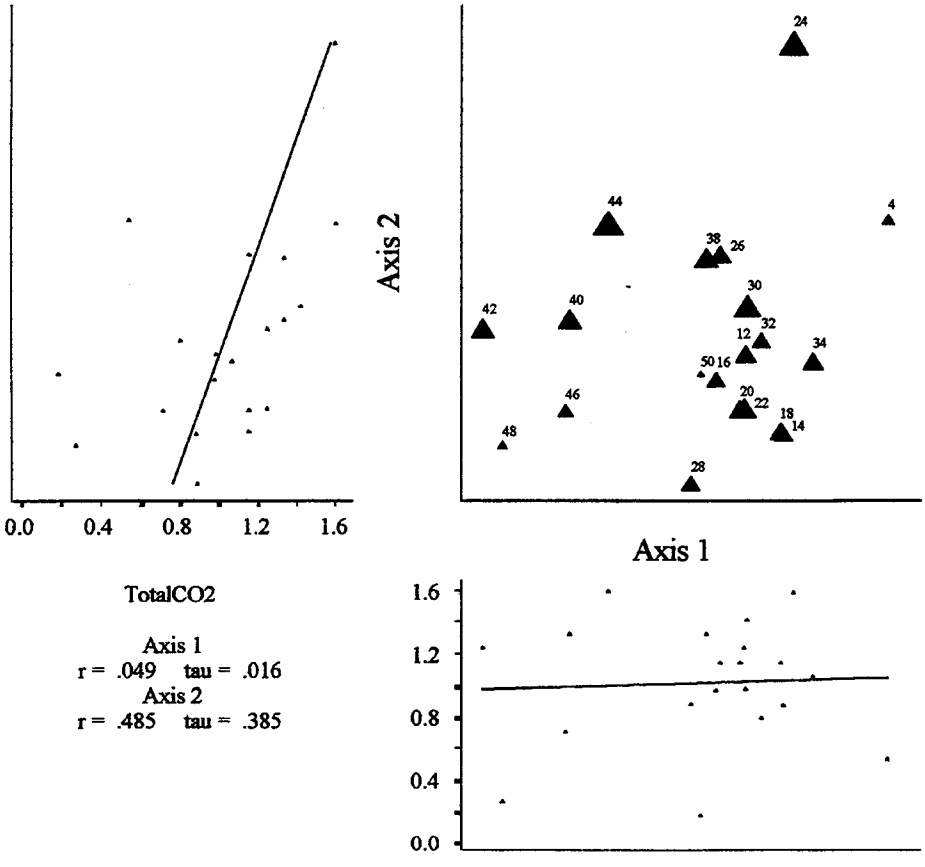


Fig. 3.10 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, correlation with field respiration. (Field respiration values, minus outliers su6 and su8: strong positive slope and correlation (r=0.49) on axis 2)

Water-amended respiration values (Figure 3.11) are also missing for su42-50, increasing the strength of the negative correlation with the arthropod community structure.

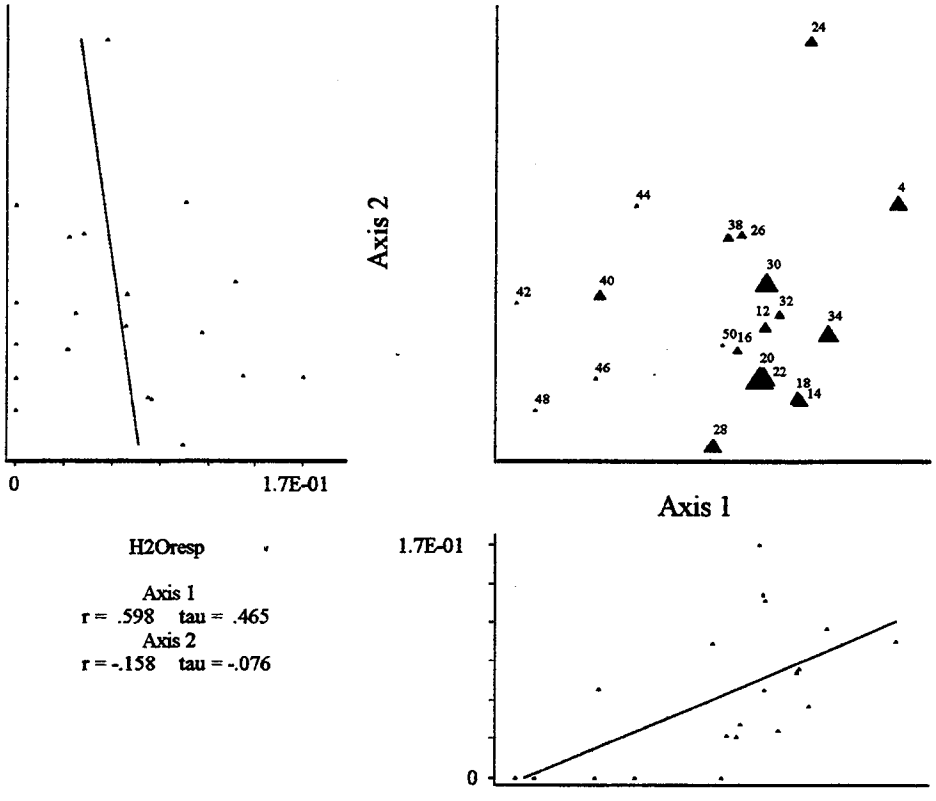


Fig. 3.11 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, minus su6 and su8, correlation with water-amended respiration values. (Strong, positive slope on axis 1 due partially to missing values (su42-50))

Substrate-induced respiration (Fig. 3.12) reveals four outliers (su20, su26, su30) and a weak positive correlation with arthropod community structure. Dissolved organic carbon (Fig. 3.13) is strongly negatively correlated with arthropod community structure along axis 1 (r= -0.5).

Soil organic matter was extremely low in sample su8, with no pattern apparent in the remaining samples after the removal of su6 and su8 (Fig. 3.14). Overlaying litter depth upon the community pattern (Figure 3.15) also reveals no correlation with soil arthropods.

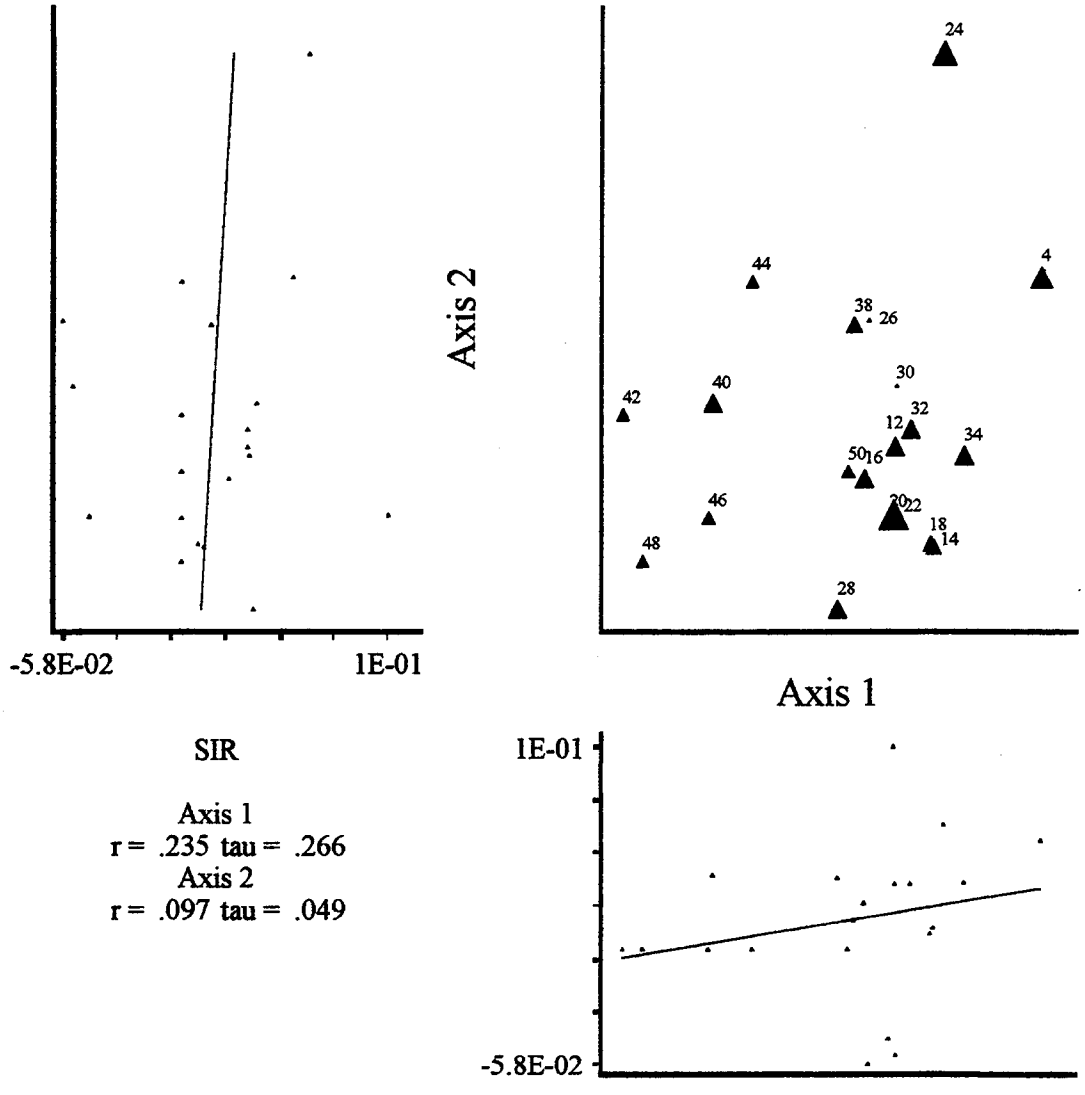


Fig. 3.12 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, -su6 and su8, correlation with substrate-induced respiration values. (Weak, positive correlation on axis 1)

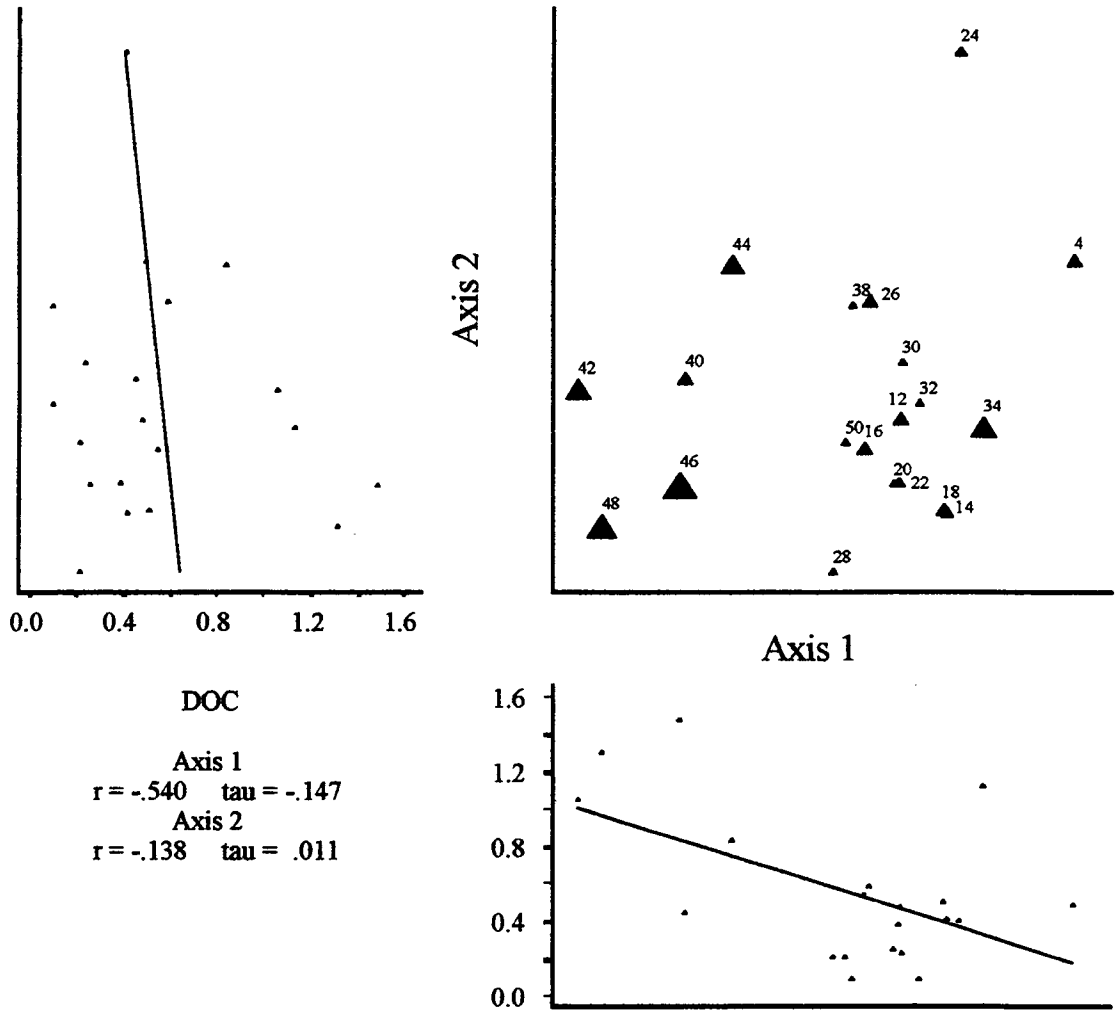


Fig. 3.13 CCA ordination, Buncom old-growth soil samples, log transformed, less 5%, minus su6 and su8, correlation with dissolved organic carbon values. (Strong negative correlation (r=-0.5) on axis 1; no outliers on first axis; random noise on axis 2)

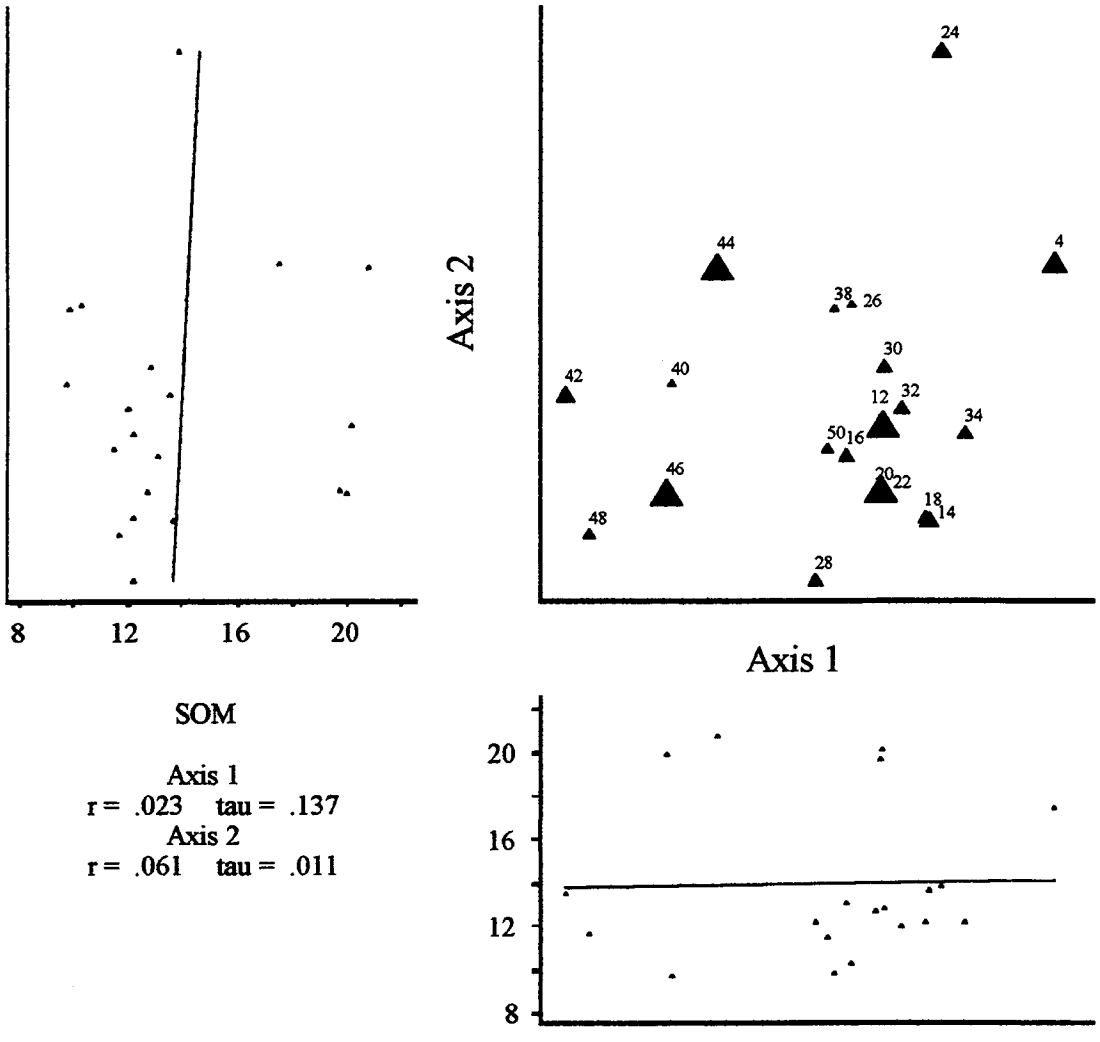


Fig. 3.14 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, minus su6 and su8, correlation with soil organic matter. (No correlation on either axis)

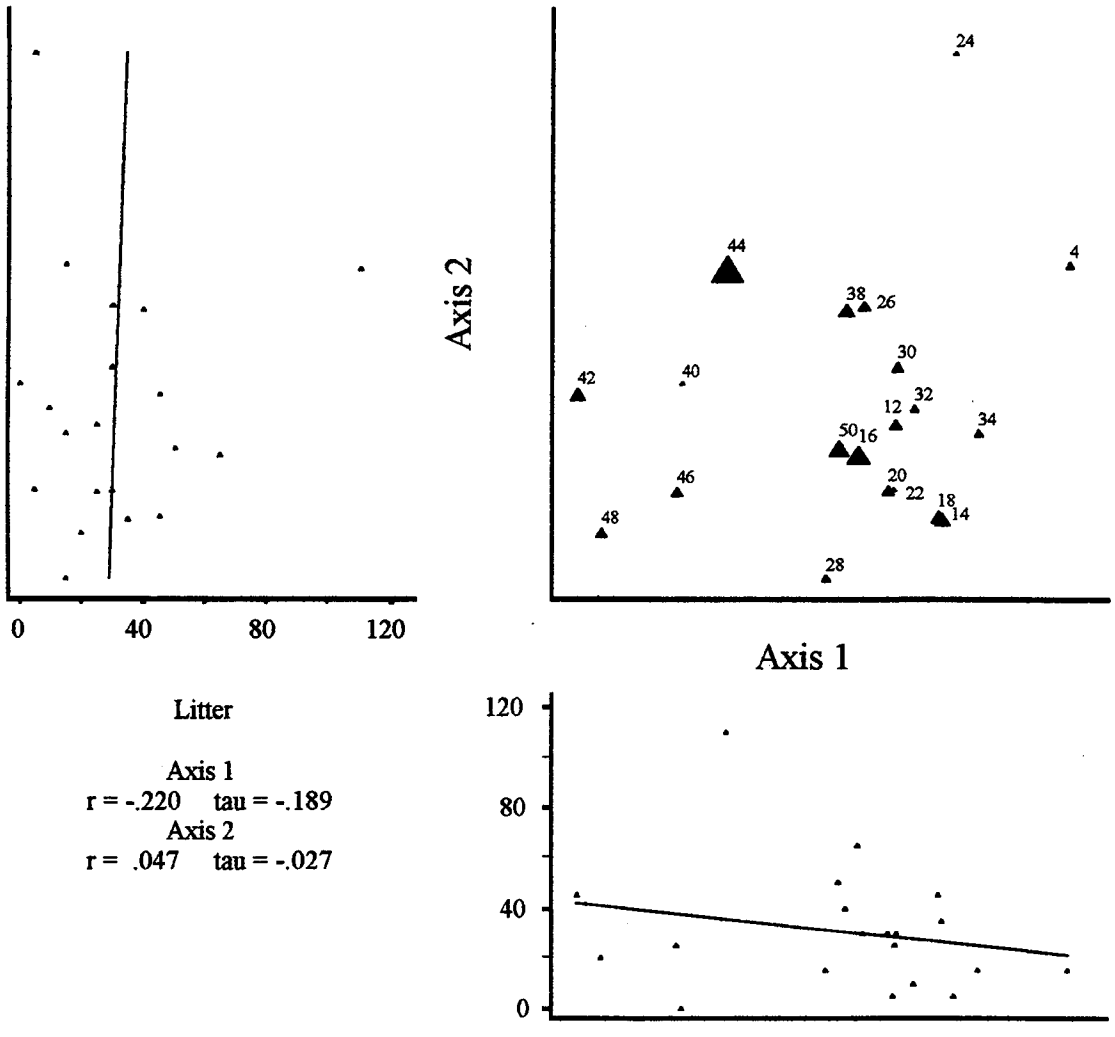


Fig. 3.15 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, minus su6 and su8 correlation with litter depth. (No correlation on either axis, su44 is an outlier)

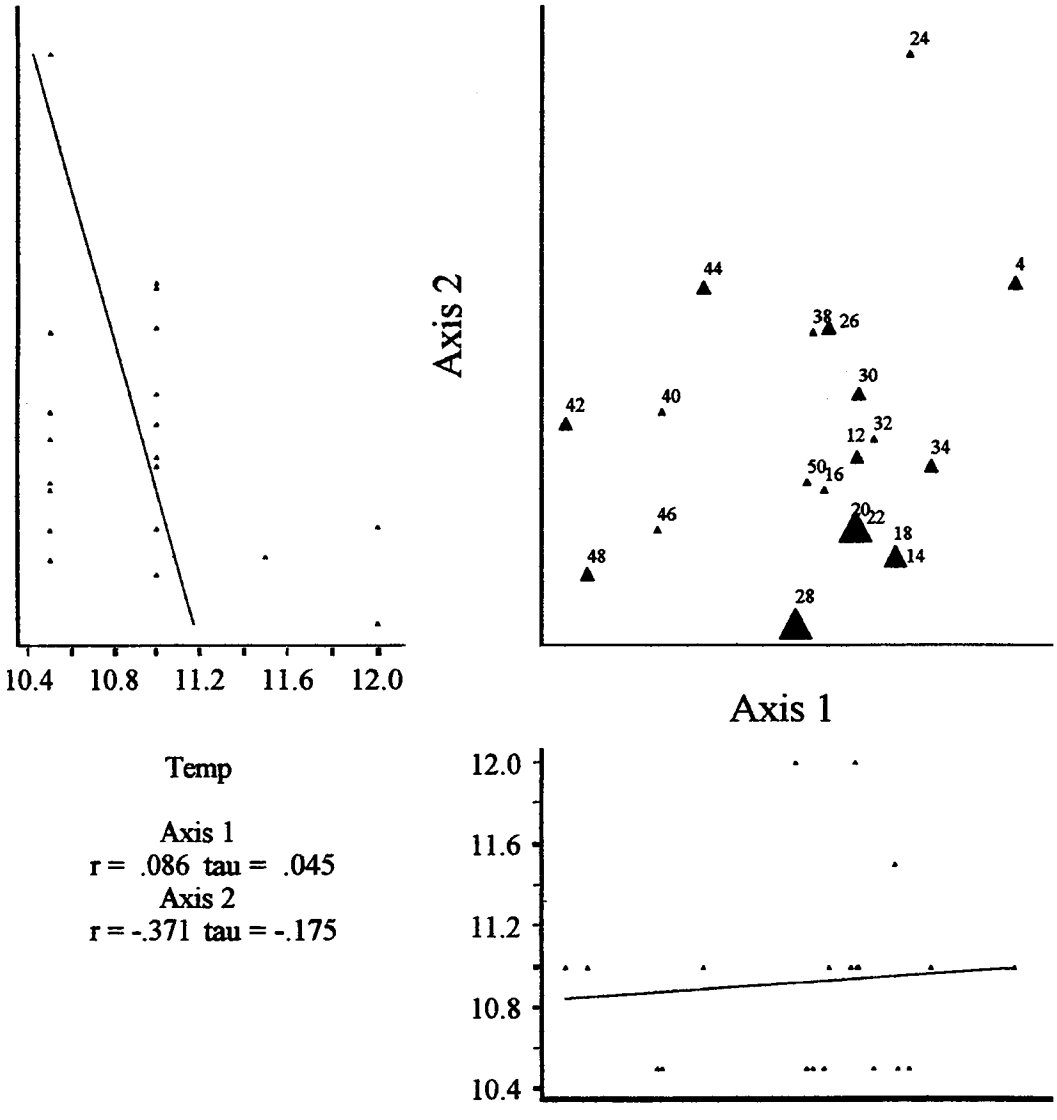


Fig. 3.16 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, minus su6 and su8, correlation with soil temperature. (No pattern on axis 1; weak negative correlation on axis 2)

Soil temperature was extremely high in su8 (Figure 3.16). With sample su8 removed, there is a weak negative correlation with soil arthropods along axis 2, but the r-value is low along axis 1. Soil pH does not reveal a correlation with the arthropod fauna (Fig. 3.17).

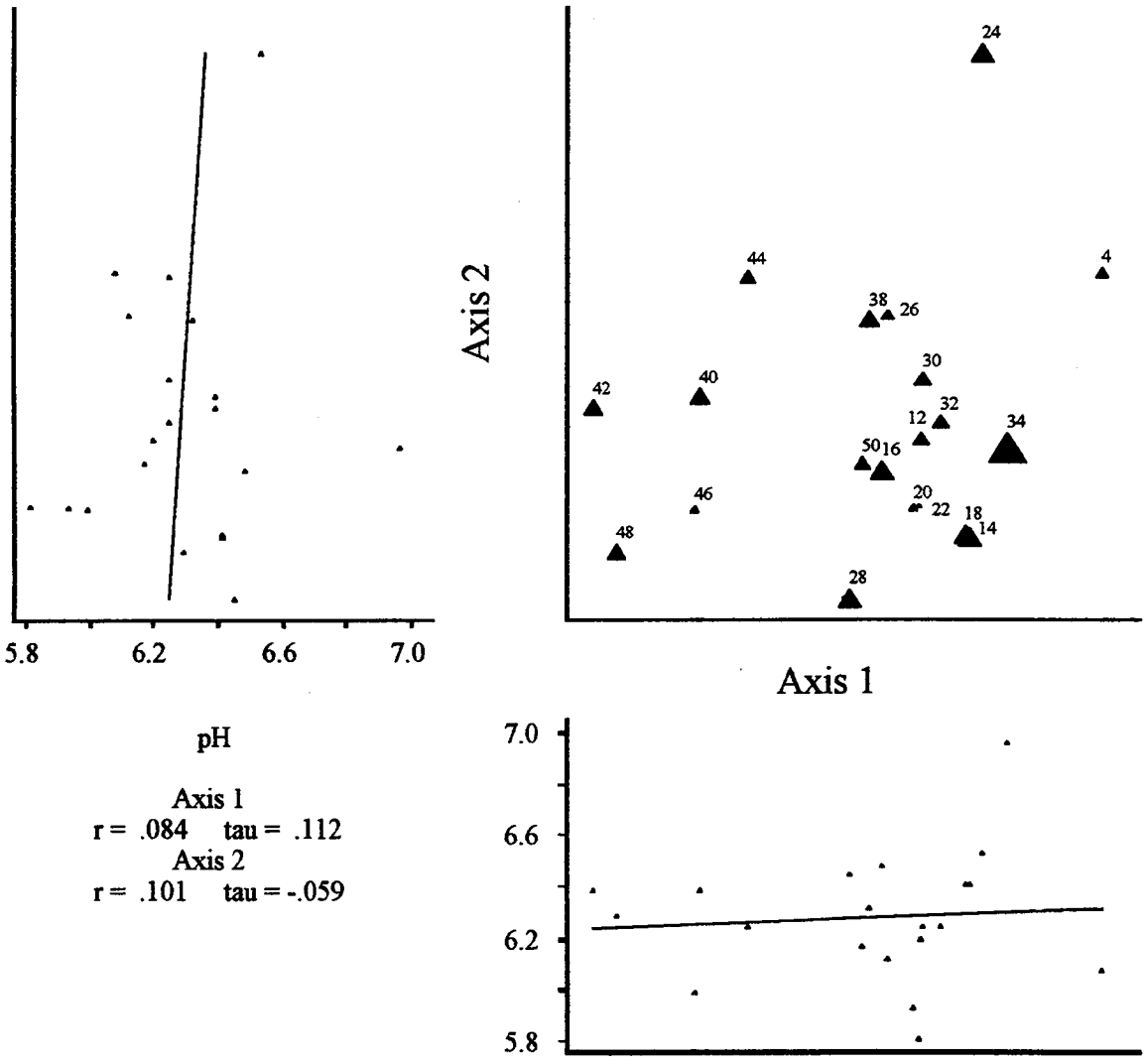


Fig. 3.17 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, correlation with pH. (Fairly uniform pH, after elimination of outlier su6 and su8)

Soil moisture (as percent moisture, Fig. 3.18) is strongly correlated along axis 1 with the arthropod community. The high moisture values of samples su42-50 define the strong negative slope.

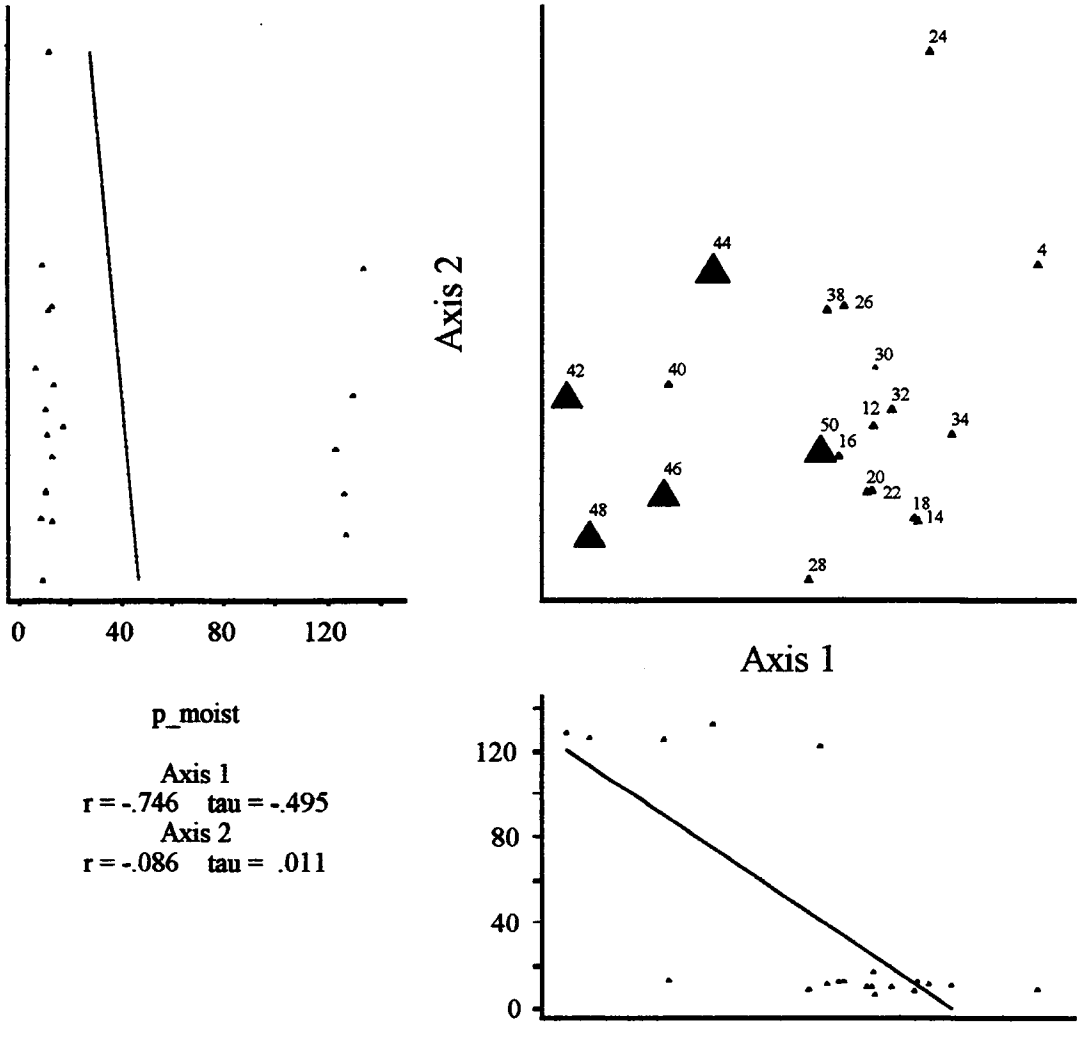


Fig. 3.18 CCA ordination, Buncom old-growth soil samples, log transformation, less 5%, minus su6 and su8, correlation with percent moisture. (Strong negative slope along axis 1, weak negative slope along axis 2)

Finally, Figure 3.19 demonstrates a strong correlation between physical juxtaposition along the transect and arthropod community composition along axis 1 and a near-zero slope on axis 2. This pattern became much stronger after the elimination of the outliers su6 and su8.

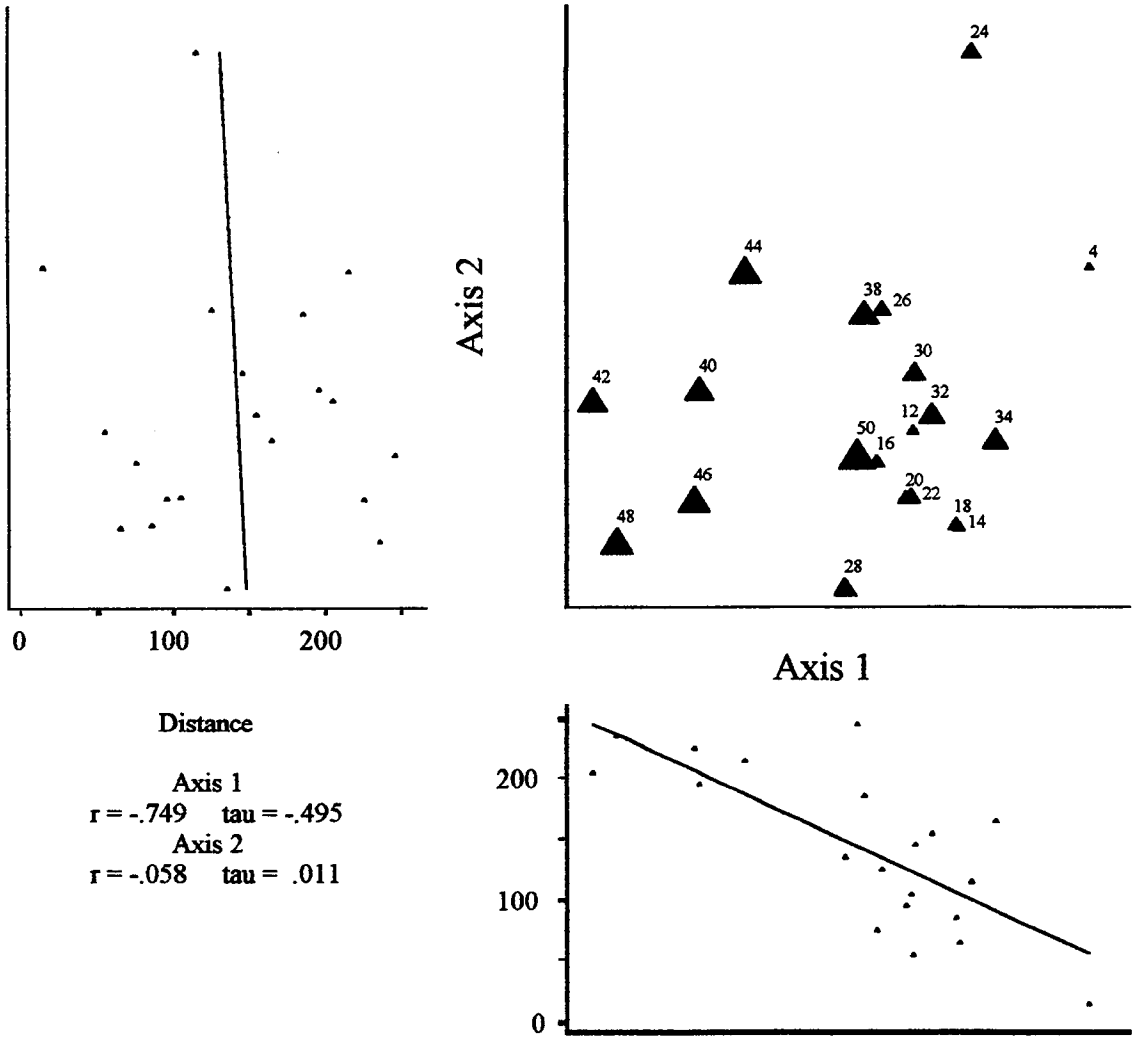


Fig. 3.19 CCA ordination, Buncom old-growth soil samples, log transformed, minus species occurring in less than 5% of all samples, correlated with distance from the end of transect. (Strong slope on axis 1 after removal of outlier su6 and su8; r=-0.7)

Figure 3.20 graphically portrays the ordination of both the microhabitat variables and the arthropod community structures. High values of percent moisture and dissolved organic carbon are characteristic of sample units on the left (su42-su50). High values of denitrification, lab respiration and temperature characterize samples in the lower right corner. The outlier, su24, is characterized by high field respiration and net mineralizable nitrogen.

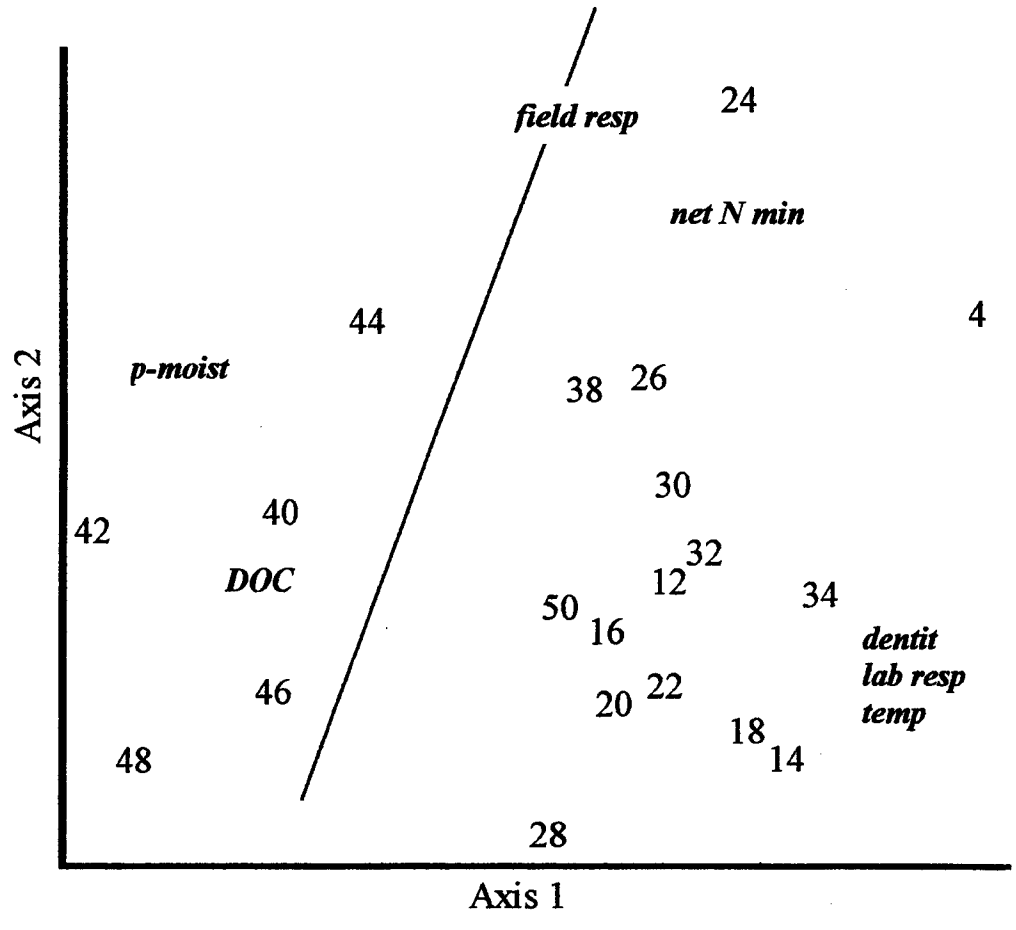


Fig. 3.20 CCA ordination, log transformed, minus species occurring in less than 5% , minus outliers su6 and su 8, of Buncom old-growth soil samples, with overlay of microhabitat variables.

The individual species of arthropods most abundant in the contrasting communities are indicated in Figure 3.21. First group (as grouped by outlier 24): *Quadroppia sp.* (QUAD), *Pthiracarus sp. 1* (PHTH1), *Rhinosuctobelba diceratosa* (RHINO), *Odontodameus sp.* (ODONT), *Oribotritia sp.* (ORIBO), and *Peltenualia sp.* (PELTE). Second group (related to percent moisture and dissolved organic carbon): *Propelops sp.* (PROPE), *Xenillus sp.* (XENI), *Sphaerochthonius sp.* (SPHAER), *Oribatula sp.* (ORIBU), *Sphodrocepheus sp.* (SPHOD), and *Scheloribates sp.* (SCHEL). Third group (related to high soil temperatures, denitrification and lab respiration): *Agulla sp.* (AGUL),

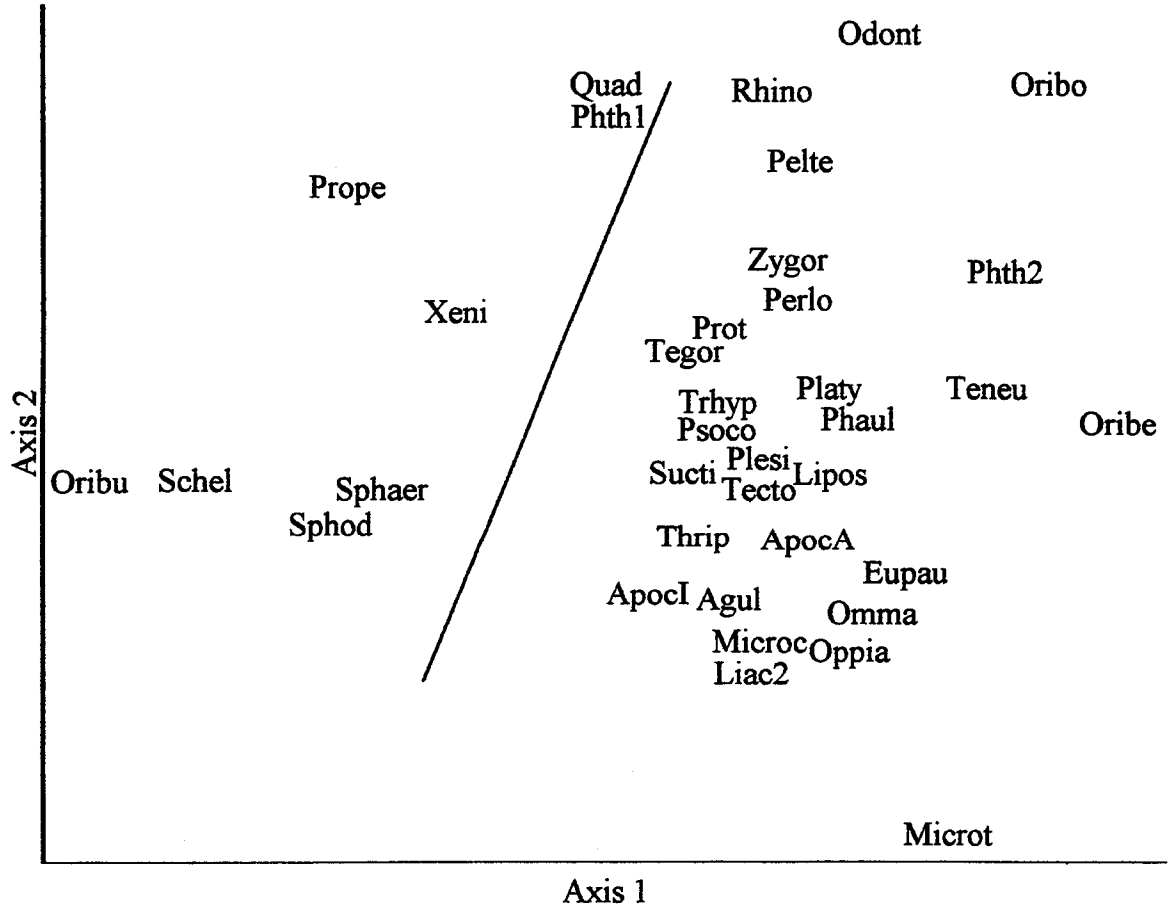


Fig. 3.21 CCA ordination, log transformed, minus species occurring in less than 5% of samples and minus outliers su6 and su8, of Buncom old-growth soil fauna.

Apocthonius sp (APOCA), Eupauropod (EUPAU), *Ommatocepheus sp.* (OMMA), *Microcreagus sp.* (MICROC), *Microtritia sp.* (MICROT), *Oppia sp.* (OPPIA), and *Liacarus sp. 2* (LIAC). Undifferentiated: *Zygoribatula sp.* (ZYGOR), *Phthiracarus sp.* 2 (PHTH2), *Perlohmannia sp.* (PERLO), Thrips (THRIP), Protura (PROT), *Tegoribates sp.* (TEGOR), *Platynothrus sp.* (PLATY), *Teneuiala sp.* (TENEU), *Trhypochthonius sp.* (TRHYP), *Phauloppia sp.* (PHAUL), *Oribatella sp.* (ORIBE), Psocopteran (PSOCO), *Plesiotritia megale* (PLESI), *Suctobelbella sp.* (SUCTI), *Liposcelis sp.* (LIPOS), *Tectocepheus sp.* (TECTO), and *Apocthonius sp.* Immatures (APOCI).

Table 3.5 Summary of Buncom old-growth correlates.

Outlier samples to be removed from analysis	su8 – microbial outlier su6 – arthropod outlier
Soil organic matter and litter depth	No correlation with arthropods
Soil moisture and water-amended respiration	Strong correlates of arthropods; Inversely correlated with one another
Dissolved organic carbon	Correlates with arthropods, and with soil moisture and water-amended resp.
Field respiration and lab respiration	Field respiration strongly correlated with axis 2; lab resp. values intermediate
Extractable ammonium and net mineralizable nitrogen	Strong, positive correlation with arthropod composition; Extr. amm. weakly correlates.
Microhabitats	Samples 42-50 wetter, with low lab respiration, low water-amended respiration, low net mineralizable nitrogen, but with dissimilar arthropod compositions.

Discussion

High vegetative diversity, high precipitation, and predictable climatic conditions usually increase arthropod species richness (Samways 1994). Soil mite and collembola abundance depends strongly on soil type, texture, temperature, moisture, and soil organic matter (Larink 1997). Vertical and horizontal distributions of soil microarthropods are determined in part by pH, soil temperature and soil porosity (Larink 1997). Intense disturbance of the soil through human activity, i.e. logging and burning, disrupts and alters soil microarthropod communities, usually causing populations to initially crash (reduction of >50% of the mean annual densities) (Blair and Crossley 1988). Recovery of the community to pre-disturbance conditions is slow and legacies of disturbance can still be detected after thirty-five years (Estrada-Venegas 1995). Measures of the above abiotic and environmental parameters should correlate with patterns of soil microarthropod species richness and abundance. I expected that there would be within-stand heterogeneity and particular microhabitat descriptors amongst which the arthropods would differentiate and form associated communities. This hypothesis was based in part upon the expectation of strong host-plant/insect relationships (Strong *et al.* 1984), the widely observed correlation between litter depth, soil organic matter and microarthropods (Coleman and Crossley 1995), and the basic natural history of any species, which dictates its environmental preferences.

This study's lack of repeatable, strongly differentiated patterns of correlation analysis with even a single variable is surprising. This result may indicate that the most

commonly measured physical and microbial descriptors are unlikely to relate closely to soil arthropod community composition. Deharveng and Bedos (1993), in a similar study, also did not find any dominant environmental parameter capable of explaining the complex patterns of diversity and abundance that emerged from their data.

This analysis included very diverse taxa. It is possible that, at this scale of analysis and given the complexity of belowground systems, any patterns generated by individual species were rendered undetectable by other species generating other patterns. This hypothesis could be tested with study of the natural histories of the species involved and further analysis.

Ordination analysis defined the arthropod communities at each of the distinct research sites. Ordination analysis usually can identify indicator species characteristic of contrasting microhabitats. However, at the scale of analysis herein considered, ordination consistently produced a single cloud of points (occasionally with outliers) indicating a relative homogeneity in the community structure of arthropods at each of the 6 stands. The lack of distinctly different microhabitat clouds precluded the testing of any environmental variable (or summed variables) against the density of individual species of arthropods.

Data resolved to the level of genus was occasionally necessary to employ in this analysis. Not differentiating between species with in a genus may have contributed to not detecting any correlation between arthropod community composition and the measured environmental parameters at this scale. Since a generic level of taxonomic resolution did not seem to hinder patterns in related soil arthropod studies (Estrada-Venegas 1995,

Moldenke 1996a, 1996b), it is unlikely to have generated enough noise in the data to have removed significant correlation here.

One environmental variable is unlikely to fully determine a species' distribution in any community. Rather, a combination of environmental variables and species interactions is a more probable determinant of species distributions. Statistically and analytically, a weighted effect for combined environmental parameters is difficult to determine and apply in analysis. Regardless, I think it is significant that we employed a large range of the most widely used soil descriptors and still found only very limited, unpredictable, and largely, site specific, patterns.

Although there was some indication of arthropod response correlating with the microbial variables at five of the six sites, one site (Buncom old-growth) displayed a series of strong correlates (especially after two outliers were removed). Ordination scores along the first and most important axis were positively correlated with dissolved organic carbon and percent moisture. Such a situation can arise as increasing dryness shuts down microbial cellular respiration, but exoenzyme catabolism of carbohydrates continues and builds up a pool of unutilized labile organic carbon. Under the assay conditions, when water is added to the controls for the SIR assay, the added water makes this labile carbon available to the microorganisms resulting in elevated in vitro soil respiration rates. Such a scenario would explain the lack of a substrate-induced respiration response, since the labile carbon is being utilized by microorganisms in the non-glucose amended controls. Under these conditions, the addition of the glucose has very little additional stimulatory effect. The negative correlation between field respiration and soil temperature probably

reflects some indirect moisture effect; where moisture becomes limiting to respiration in warmer soils where moisture is reduced.

The first ordination axis correlates positively with mineralizable nitrogen, lab respiration and water-amended respiration and negatively with percent moisture, distance from the start of the transect and soil moisture. The second ordination axis correlates positively with field respiration. High levels of field respiration may indicate synchronous high activities of microbial decomposers, plant root uptake and arthropod grazing; all of which may have differing net effects on soil processes. At different locations along a transect, different sources of soil respiration may result in different soil processes when respiration is elevated.

A correlation between arthropod species composition and field respiration was direct at Buncom old-growth, but indirect at the two Panther Gap sites (about the only other correlates observed at these six sites). The Panther Gap old-growth community was also strongly correlated with two of the strong microhabitat correlates at Buncom old-growth (field respiration and denitrification). Field respiration was also positively correlated, but more weakly, at Thompson Creek old-growth. The other microhabitat variables did not correlate. This lack of consistency in demonstrable patterns highlights the major observations of this study, namely, few significant correlates between sites.

Conclusions

The correlation between microbial ecological variables and arthropod community composition, in general, is weak, with only a few exceptions. Total field respiration is the

most likely characteristic to correlate with arthropods; correlating 83% of the time (5 out of 6 stands). Soil moisture, which might be expected to correlate with arthropod composition, was strongly correlated only at the Buncom sites. Old-growth sites generally had three or four strong correlates, but the correlates were not consistent between old-growth sites. In general, there were fewer strongly correlated variables in the younger stands than in the old-growth stands.

The lack of significant correlation between microhabitat variables and soil arthropods implies a temporal and/or spatial mismatch between the two sets of measures. Microarthropods, particularly the oribatids, are long-lived organisms in comparison to microbial organisms, thereby generating a relative temporal gap (microbial fast, microarthropods slow) in their responses to stand conditions. Differences in size and mobility allow microbes and microarthropods to respond on different spatial scales, thus creating different patterns of distribution throughout a site.

Future studies examining the determinants of microarthropod diversity and spatial heterogeneity need well-devised statistical sampling designs to ensure an appropriate degree of geographic replication and to avoid the problem of pseudo-replication. A weakness of this study was the use of judgement sampling to select a single transect through the stand. Secondly, a multiple-stage sampling design should have been used to select several transect lines, randomly across the stand, and assign random sampling points along the transects. This would have ensured greater independence amongst the samples. A stratified random sample design could be incorporated to address the heterogeneity of microhabitats across the stand (e.g. near trees, in gaps, areas of high field respiration vs.

low field respiration, etc...). Stratified sampling would probably yield higher resolution of patterns between the arthropod community and microhabitat variables.

Thesis Summary

During the last decade, agencies charged with the management of public lands have been shifting management goals to maintain ecosystem processes, species diversity and habitat on forested lands, in addition to the traditional management goals of timber production and recreation. Thinning is the silvicultural practice of reducing stand density through the partial removal of the overstory canopy. This practice has been recognized as the primary tool for public land managers to hasten the development of structural heterogeneity and habitat within young and middle-aged stands.

Arthropods are integral parts to a functioning forest ecosystem and perform key roles as detritivores, herbivores, predators and prey. The purpose of this study was to examine how thinning alters the biological diversity and community composition of soil and litter arthropods compared to unthinned, mid-age and old-growth stands. The secondary purpose was to identify microhabitat variables responsible for driving biodiversity within stands.

On a multi-regional scale, such as Western Oregon, regional and climatic differences were clearly the strongest determinants of arthropod community composition; far stronger than any management effect. Within regions, locale differences were a stronger influence upon community composition than management protocols. An exception was in the litter community, where stand management differences overwhelmed triad effects. The litter community is less mobile than the pitfall community and more susceptible to alteration than the soil community. The litter community therefore is more

likely to respond more readily to different stand management strategies and follow the successional stages of the plant community.

The findings of this study have several implications. If the primary concern is general arthropod diversity, being in some fashion representative of total system " unseen diversity" (Franklin, personal communication), then there is neither: a) one method or quick assay of diversity (e.g. pitfall trapping) that will encompass the many-fold species to ascertain their relative abundance or habitat preferences; nor b) a single environmental determinant (e.g. soil organic matter) that will significantly effect a wide-enough spectrum of the arthropod diversity to be detectable at this scale. Theoretically, multiple taxa may create noise that can cancel out patterns of individual taxa, as well as reinforce individual patterns. In this case it appears that the broadness of the diversity of the taxa created noise, rather than defining patterns. An alternative approach could focus in-depth on individual taxa, or a limited combination of taxa. At this scale, it will be possible to ascertain species' microhabitat preferences, however, this approach obviates the possibility of "indicator species" to represent a wider spectrum of biodiversity.

The use of indicator taxa as surrogates for measuring overall arthropod diversity is another possible method. As this study has ascertained, however, there is no one pattern that can be successfully correlated across taxa or species. Therefore, in using indicator taxa to make management decisions, one runs the risk of losing diversity. A combination of several indicator taxa, each with distinct needs and habitats, may, however, serve as the best method for ascertaining arthropod diversity on a large-scale, either through time or

space. A combination of indicator taxa would more specifically address study concerns and be more practical given time and resource limitations.

Future studies, instead of attempting to focus on overall diversity, should focus on particular groups of arthropods, either for management or economic reasons. For example, if one is concerned about prey availability for vertebrates, then a specific study examining the habits and habitats of the species that the vertebrate is known to feed upon will be the most effective.

If one is concerned about managing for the greatest number of arthropods and their individual needs, then the maintenance of heterogeneous habitats across the landscape is essential. To encompass the greatest number of individual arthropod needs, it is necessary to maintain a dynamic and large-scale patchwork of forest stands across space and time. This will more closely approximate the historical landscape of heterogeneous habitats prior to white settlement and large-scale anthropocentric alteration than any fixed-stand or refuge solution, and therefore provide a maximum number of habitats for Pacific Northwest forest arthropod species. The results of this study have shown that there is no one management strategy that is the best overall for arthropod diversity and community composition, but rather, it is a combination of management strategies that promotes overall diversity. While this study found few strong correlates between structural heterogeneity and arthropod diversity, I suspect that these findings were in part due to scale and that individual taxa do respond spatially and temporally to alterations of habitat.

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APPENDIX

Species List

BLM Thinning Project

Species List

Order	Sub-order	Family	Genus	Species	ID	Trophic level	Life stage	Description	Biomass	Method *
Acari	**Acaridida**	**Acaridae**	*Tyrophagus*	*sp.*	Tyrophagus	Fungivore			5	SL
Acari	Acaridida	Acaridae		*sp. 1*	Acarid	Omnivore				L
Acari	**Actinedida**	**Anystidae**		*sp. 1*	Anystid	Predator				L
Acari	Actinedida	**Bdellidae**	*Cyta*	*sp.*	Cyta	Predator	Adult		75	PLS
Acari	Actinedida	**Caeculidae**	*Caecula*	*sp.*	Caecula	Predator				L
Acari	Actinedida	**Cunaxidae**		*sp. 1*	Cunaxidae	Predator				L
Acari	Actinedida	**Labidostommatidae**	*Labidostoma*	*sp. 1*	Labidostoma	Predator		Small	220	SL
Acari	Actinedida	Labidostommatidae	*Labidostoma*	*sp. 2*	Labidostoma	Predator		Regular	400	SL
Acari	Actinedida	**Nanorchestidae**	*Nanorchestes*	*sp. 1*	Nanorchestes	Fungivore		Orange	1	SL
Acari	Actinedida	Nanorchestidae	*Nanorchestes*	*sp. 2*	Nanorchestes	Fungivore		Regular	1	SL
Acari	Actinedida	**Rhagidiidae**		*sp.1*	Rhagidiid	Predator			40	SL
Acari	Actinedida	**Trombidiidae**		*sp.1*	Trombidiid	Predator	Adult		500	PLS
Acari	Actinedida			*sp.1*	Endeostigmata	Fungivore			1	SL
Acari	**Gamasida**	**Traychytidae**	*Traychytes*	*sp. 1*	Traychetes	Predator		Regular	300	SL
Acari	Gamasida	Traychytidae	*Traychytes*	*sp. 2*	Traychetes	Predator		AFC	800	SL
Acari	Gamasida	**Uropodidae**		*sp. 1*	Uropodid	Predator		Penny Round	390	S(A,I)L(A,I)
Acari	Gamasida	Uropodidae		*sp. 2*	Uropodid	Predator		Penny Front	280	SL
Acari	Gamasida	Uropodidae		*sp. 3*	Uropodid	Predator		Penny Small (sp. PS)	80	SL
Acari	Gamasida	Uropodidae		*sp. 4*	Uropodid	Predator		FAS	390	SL
Acari	Gamasida	**Zerconidae**	*Zercon*	*sp.*	Zercon	Predator			9	SL
Acari	Gamasida			*sp. 1*	Mesostigmata	Predator			75	P(A)L(A,I)S(A,I)
Acari	Gamasida			*sp. 2*	Micromesostigmata	Predator				L
Acari	**Ixodida**	**Ixodidae**	*Ixodes*	*sp.*	Tick	Parasite	Adult			PL
Acari	**Oribatida**	**Achipterioidea**	*Achipteria*	*sp. 1*	Achipteria	Fungivore			27	SL
Acari	Oribatida	Achipterioidea	*Achipteria*	*sp. 2*	Achipteria	Fungivore		Huge		L
Acari	Oribatida	Achipterioidea	*Anachipteria*	*sp.*	Anachipteria	Fungivore				L
Acari	Oribatida	Achipterioidea	*Tegoribates*	*sp.*	Tegoribates	Fungivore			40	SL
Acari	Oribatida	**Archeonothroidea**	*Zachvatkinella*	*sp.*	Zachvatkinella	Bacteriovore				L

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Species List con't.

Order	Sub-order	Family	Genus	Species	ID	Trophic level	Life stage	Description	Biomass	Method *
Acari	Oribatida	Carabodoidea		*sp. 1*	Carabodoidea	Fungivore		Huge	225	SL
Acari	Oribatida	Cepheoidea	*Cepheus*	*sp.*	Cepheus	Fungivore				L
Acari	Oribatida	Cepheoidea	*Eupterotegeus*	*sp*	Eupterotegeus	Fungivore				SL
Acari	Oribatida	Cepheoidea	*Ommatocepheus*	*sp.*	Ommatocepheus	Fungivore			50	SL
Acari	Oribatida	Cepheoidea	*Sphodrocepheus*	*sp.*	Sphodrocepheus	Fungivore			131	SL
Acari	Oribatida	Ceratozetoidea	*Ceratozetes*	*sp. 1*	Ceratozetes	Fungivore			5	SL
Acari	Oribatida	Ceratozetoidea	*Ceratozetes large*	*sp. 2*	Ceratozetes large	Fungivore		Large	70	SL
Acari	Oribatida	Crotonioidea	*Camisia*	*carrollii*	Camisia	Fungivore			150	SL
Acari	Oribatida	Crotonioidea	*Camisia*	*horrida*	Camisia	Fungivore			150	SL
Acari	Oribatida	Crotonioidea	*Camisia*	*seanius*	Camisia	Fungivore				L
Acari	Oribatida	Crotonioidea	*Camisia*	*sp. d*	Camisia	Fungivore				L
Acari	Oribatida	Crotonioidea	*Camisia*	*sp. X*	Camisia	Fungivore				L
Acari	Oribatida	Crotonioidea	*Platynothrus*	*sp.*	Platynothrus	Fungivore			250	SL
Acari	Oribatida	Crotonioidea	*Trhypochthonius*	*sp.*	Trhypochthonius	Fungivore			30	SL
Acari	Oribatida	Cymbaeremaeoidea	*Coropoculia*	*sp.*	Coropoculia	Fungivore				L
Acari	Oribatida	Damaeoidea	*Belba*	*californica*	Belba	Fungivore			120	SL
Acari	Oribatida	Damaeoidea	*Belba (new genus)*	*sp.*	Belba new genus	Fungivore		New genus	85	SL
Acari	Oribatida	Damaeoidea	*Caenobelba*	*sp.*	Caenobelba	Fungivore			40	SL
Acari	Oribatida	Damaeoidea	*Epidamaeus*	*sp.*	Epidamaeus	Fungivore			9	SL
Acari	Oribatida	Damaeoidea	*Hungarobelba*	*sp.*	Hungarobelba	Fungivore			4	SL
Acari	Oribatida	Epilohmannioidea	*Epilohmannia*	*sp.*	Epilohmannia	Detritivore		New genus	320	SL
Acari	Oribatida	Eremaeoidea	*Eremaeus*	*sithos*	Eremaeus	Fungivore			53	SL
Acari	Oribatida	Eulohmannioidea	*Eulohmannia*	*sp.*	Eulohmannia	Bacteriovore			48	SL
Acari	Oribatida	Euphthiracaroidea	*Euphthiracarus*	*sp.*	Euphthiracarus	Detritivore			50	SL
Acari	Oribatida	Euphthiracaroidea	*Microtritia*	*sp.*	Microtritia	Detritivore			5	SL
Acari	Oribatida	Euphthiracaroidea	*Oribotritia*	*sp.*	Oribotritia	Fungivore			210	SL
Acari	Oribatida	Euphthiracaroidea	*Plesiotritia*	*megale*	Plesiotritia	Detritivore			390	SL
Acari	Oribatida	Galumnoidea	*Galumna*	*sp.*	Galumna	Predator			195	SL
Acari	Oribatida	Gustavioidea	*Ceratoppia*	*sp. 1*	Ceratoppia	Fungivore		Regular	40	SL

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Species List con't.

Order	Sub-order	Family	Genus	Species	ID	Trophic level	Life stage	Description	Biomass	Method *
Acari	Oribatida	Gustavioidea	*Liacarus*	*sp. 1*	Liacarus	Fungivore			27	SL
Acari	Oribatida	Gustavioidea	*Liacarus*	*sp. 2*	Liacarus	Fungivore		Big Black	188	SL
Acari	Oribatida	Gustavioidea	*Liacarus*	*sp. 3*	Liacarus	Fungivore		(was sp. T)		L
Acari	Oribatida	Gustavioidea	*Metrioppia*	*sp.*	Metroppia	Fungivore			11	SL
Acari	Oribatida	Gustavioidea	*Peltenuiala*	*sp.*	Peltenuiala	Fungivore			130	SL
Acari	Oribatida	Gustavioidea	*Teneuiala*	*sp.*	Teneuiala	Bacteriovore			270	SL
Acari	Oribatida	Gustavioidea	*Xenillus*	*sp.*	Xenillus	Fungivore			220	SL
Acari	Oribatida	**Hermannielloidea**	*Hermanniella*	*sp. 1*	Hermanniella	Fungivore			33	SL
Acari	Oribatida	Hermannielloidea	*Hermanniella*	*sp. 2*	Hermanniella	Fungivore		Big	100	SL
Acari	Oribatida	**Hermannioidea**	*Hermannia*	*sp.*	Hermannia	Fungivore			110	SL
Acari	Oribatida	**Hypochthonioidea**	*Eohypochthonius*	*sp*	Eohypochthonius	Bacterivore			10	S
Acari	Oribatida	Hypochthonioidea	*Hypochthoniella*	*sp.*	Hypoella	Bacteriovore			9	SL
Acari	Oribatida	Hypochthonioidea	*Hypochthonius*	*sp.*	Hypochthonius	Bacteriovore			21	SL
Acari	Oribatida	**Nanhermannioidea**	*Nanhermannia*	*sp.*	Nanhermannia	Fungivore			15	SL
Acari	Oribatida	**Oppioidea**	*Oppia*	*sp.*	Oppia	Fungivore			16	SL
Acari	Oribatida	Oppioidea	*Oppiella*	*sp.*	Oppiella	Fungivore			5	SL
Acari	Oribatida	Oppioidea	*Quadroppia*	*sp.*	Quadroppia	Bacteriovore			1	SL
Acari	Oribatida	Oppioidea	*Rhinosuctobelba*	*diceratosa*	Rhinosuctobelba	Bacteriovore			60	SL
Acari	Oribatida	Oppioidea	*Suctobelbella*	*sp.*	Suctobelbella	Fungivore			2	SL
Acari	Oribatida	**Oribatelloidea**	*Oribatella*	*sp.*	Oribatella	Fungivore			13	SL
Acari	Oribatida	**Oripodoidea**	*Eporibatula*	*sp.*	Eporibatula	Bacteriovore			1	SL
Acari	Oribatida	Oripodoidea	*Oribatula*	*sp.*	Oribatula	Fungivore				SL
Acari	Oribatida	Oripodoidea	*Phauloppia*	*sp.*	Phauloppia	Fungivore			11	SL
Acari	Oribatida	Oripodoidea	*Scheloribates*	*sp.*	Scheloribates	Fungivore			14	SL
Acari	Oribatida	Oripodoidea	*Zygoribatula*	*sp*	Zygoribatula	Fungivore			16	SL
Acari	Oribatida	**Periohmannia**	*Periohmannia*	*sp.*	Periohmannia	Fungivore			220	SL
Acari	Oribatida	**Phenopelopoidea**	*Eupelops*	*sp.*	Eupelops	Bacteriovore		(=Pelops)	180	SL
Acari	Oribatida	Phenopelopoidea	*Propelops*	*sp.*	Propelops	Fungivore			34	SL
Acari	Oribatida	**Phthiracaroidea**	*Phthiracarus*	*sp. 1*	Phthiracarus	Detritivore			27	SL

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Species List con't.

Order	Sub-order	Family	Genus	Species	ID	Trophic level	Life stage	Description	Biomass	Method *
Acari	Oribatida	**Protoplophoroidea**	*Cosmochthonius*	*sp.*	Cosmochthonius	Bacteriovore			1	SL
Acari	Oribatida	Protoplophoroidea	*Sphaerochthonius*	*sp.*	Sphaerochthonius	Bacteriovore			1	SL
Acari	Oribatida	**Tectocepheoidea**	*Tectocepheus*	*sp.*	Tectocepheus	Fungivore			5	SL
Acari	Oribatida				Immatures	Omnivore	Immature		5	SL
Annelida		**Enchytraeidae**			Enchytraeid	Detritivore			18000	SL
Annelida		**Lumbricidae**			Earthworm	Fungivore	Adult			PL
Annellida		**Megascolecthidae**	*Arctiostrotus*	*perreyi*	Arctiostrotus	Fungivore	Adult			P
Araneae		**Agelenidae**	*Callymaria*	*sp.*	Callymaria	Predator	Adult			P
Araneae		Agelenidae	*Cybaeus*	*sp.*	Cybaeus	Predator	Immature		13900	SL
Araneae		Agelenidae	*Cybaeus*	*sp.1*	Cybaeus 3	Predator	Adult	3		P
Araneae		Agelenidae	*Cybaeus*	*sp.2*	Cybaeus 4	Predator	Adult	4		P
Araneae		Agelenidae	*Cybaeus*	*sp.3*	Cybaeus 5	Predator	Adult	5		P
Araneae		Agelenidae	*Cybaeus*	*sp.4*	Cybaeus 7	Predator	Adult	7		P
Araneae		Agelenidae	*Cybaeus*	*sp.5*	Cybaeus 10	Predator	Adult	10		P
Araneae		Agelenidae	*Cybaeus*	*sp.6*	Cybaeus 13	Predator	Adult	13		P
Araneae		Agelenidae	*Cybaeus*	*sp.7*	Cybaeus 17	Predator	Adult	17		P
Araneae		Agelenidae	*Cybaeus*	*sp.8*	Cybaeus striped F	Predator	Adult	striped		P
Araneae		Agelenidae	*Cybaeus*	*sp.9*	Cybaeus TW	Predator	Adult	TW		P
Araneae		Agelenidae		*sp. 1*	Agelenid Small	Predator	Adult	Small		P
Araneae		Agelenidae		*sp. 2*	Agelenid Tiny	Predator	Adult	Tiny		P
Araneae		Agelenidae		*sp. 3*	Agelenid	Predator	Adult			PL
Araneae		**Amaurobiidae**	*Callobius*	*sp. 1*	Callobius 10	Predator	Adult	10		P
Araneae		Amaurobiidae	*Callobius*	*sp. 2*	Callobius 15 M	Predator	Adult	15		P
Araneae		Amaurobiidae	*Microamaurobius*	*sp.*	Microamaurobius	Predator	Adult			P
Araneae		Amaurobiidae		*sp.*	Amaurobius	Predator	Adult			P
Araneae		**Antrodiaetidae**	*Antrodiaetus*	*occultus*	Antrodiaetus Tiny	Predator	Adult	Tiny		P
Araneae		Antrodiaetidae	*Antrodiaetus*	*pacificus*	Antrodiaetus Huge	Predator	Adult	Huge	5000	P(A,I)L(I)S(I)
Araneae		Antrodiaetidae	*Antrodiaetus*	*pagneus*	Antrodiaetus Very Huge	Predator	Adult	Very Huge		P
Araneae		**Anyphaenidae**	*Anyphaena*	*pacifica*	Anyphaena	Predator	Adult			P

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Species List con't.

Order	Sub-order	Family	Genus	Species	ID	Trophic level	Life stage	Description	Biomass	Method *
Araneae		Gnaphosidae	*Cheiracanthium*	*sp*	Cheiracanthium	Predator	Adult			P
Araneae		Gnaphosidae	*Gnaphosa*	*sp. 1*	Gnaphosa Blk	Predator	Adult			P
Araneae		Gnaphosidae	*Gnaphosa*	*sp. 2*	Gnaphosa Lg Blk	Predator	Adult	Large, Black		P
Araneae		Gnaphosidae	*Gnaphosa*	*sp. 3*	Gnaphosa Sm Blk	Predator	Adult	Small, Black		P
Araneae		Gnaphosidae	*Gnaphosa*	*sp. 4*	Gnaphosa Sm Tan	Predator	Adult	Small, Tan		P
Araneae		Gnaphosidae	*Micaria*	*sp.*	Micaria	Predator	Adult			P
Araneae		Gnaphosidae	*Phrurotimpus*	*sp.*	Phrurotimpus	Predator	Adult			P
Araneae		Gnaphosidae	*Sergiolus*	*sp.*	Sergiolus	Predator	Adult			P
Araneae		Gnaphosidae	*Zelcodes*	*sp.*	Zelcodes	Predator	Adult			P(A)L(I)
Araneae		Gnaphosidae			Gnaphosid	Predator	Immature		4500	SL
Araneae		Gnaphosidae			Micrygnaphosid	Predator	Adult			P
Araneae		Linyphiidae	*Erigone*	*sp.*	Erigone	Predator	Adult			P
Araneae		Linyphiidae	*Neriene*	*sp. 1*	Neriene	Predator	Adult			P
Araneae		Linyphiidae	*Neriene*	*sp. 2*	Neriene Large	Predator	Adult	Large		P
Araneae		Linyphiidae	*Pityohyphantes*	*sp.*	Pityohyphantes	Predator	Adult			P
Araneae		Linyphiidae	*Prolinyphia*	*sp.*	Prolinifea	Predator	Adult			P
Araneae		Linyphiidae	*Wubana*	*sp.*	Wubana	Predator	Adult			P
Araneae		Linyphiidae		*sp. 1*	Micryphantid Huge F	Predator	Adult	Huge		P
Araneae		Linyphiidae		*sp. 2*	Micryphantid Red	Predator	Adult			P
Araneae		Linyphiidae		*sp. 3*	Micryphantid Spiny	Predator	Adult			P
Araneae		Linyphiidae		*sp. 4*	Micryphantid Long Legged	Predator	Adult	Long -legged		P
Araneae		Linyphiidae		*sp. 5*	Micryphantid Very Large	Predator	Adult	Very Large		P
Araneae		Linyphiidae		*sp. 6*	Micryphantid	Predator	Adult		750	P(A)L(A,I)S(?)
Araneae		Linyphiidae			Linyphiid	Predator	Adult			P
Araneae		Lycosidae	*Lycosa*	*sp. 1*	Lycosa	Predator	Adult			P
Araneae		Lycosidae	*Lycosa*	*sp. 2*	Lycosa 13	Predator	Adult			P
Araneae		Lycosidae	*Pardosa*	*sp. 1*	Pardosa	Predator	Adult			P
Araneae		Lycosidae	*Pardosa*	*sp. 2*	Pardosa large	Predator	Adult	Large		P
Araneae		Philodromidae	*Philodromus*	*rufus*	Philodromus rufus	Predator	Adult			P

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Species List con't.

Order	Sub-order	Family	Genus	Species	ID	Trophic level	Life stage	Description	Biomass	Method *
Araneae		Salticidae	*Habronatus*	*sp.*	Habronatus	Predator	Adult			P
Araneae		Salticidae	*Neon*	*sp.*	Neon	Predator	Adult			PL
Araneae		Theridiidae	*Achaearanea*	*sp.*	Achaearanea F	Predator	Adult			P
Araneae		Theridiidae	*Dipoena*	*nigra*	Dipoena nigra	Predator	Adult			P
Araneae		Theridiidae	*Euryopis*	*sp.*	Euryopis	Predator	Adult			P
Araneae		Theridiidae	*Theridion*	*sexpunctatum*	Theridion sexpunctatum	Predator	Adult			P
Araneae		Thomisidae	*Ebo*		Ebo	Predator	Adult			P
Araneae		Thomisidae	*Misumenops*	*sp.*	Misumenops imm	Predator	Immature			P
Araneae		Thomisidae	*Xysticus*	*sp.*	Xysticus	Predator	Adult			P(A)L(A,I)
Blattaria		Cryptocercidae	*Cryptocercus*	*sp*	Cryptocercus	Detritivore	Adult			P
Chilopoda	Geophilomorpha				Geophilid	Predator			8800	PLS
Chilopoda	Lithobiomorpha				Lithobiid	Predator	Adult		7500	PLS
Chilopoda	Scolopendromorpha		*Scolopocryptops*	*sp.*	Scolopocryptops	Predator	Adult			P
Coleoptera		Anthicidae			Anthicid	Predator	Adult			P
Coleoptera		Bostrichidae			Bostrichid	Detritivore	Adult			P
Coleoptera		Byrrhidae	*Cytolysis*		Cytolysis	Herbivore Moss				L
Coleoptera		Byrrhidae	*Lioon*	*sp.*	Lioon	Herbivore	Adult	(L- Herb. Moss)		PL
Coleoptera		Byrrhidae			Byrrhid	Herbivore	Immature	L-Herb. Moss		P(A)L(A,I)
Coleoptera		Cantharidae	*Silis*	*sp.*	Silis	Predator	Adult			P
Coleoptera		Cantharidae			Cantharid	Predator	Immature		2900	PLS
Coleoptera		Carabidae	*Amara*	*sp.*	Amara	Predator	Adult			P
Coleoptera		Carabidae	*Agonum*	*sp.*	Agonum	Predator	Adult			P
Coleoptera		Carabidae	*Anisodactylus*	*sp.*	Anisodactylus	Predator	Adult			P
Coleoptera		Carabidae	*Bradycellus*	*sp.*	Bradycellus	Predator			1200	SL
Coleoptera		Carabidae	*Carabus*	*sp.*	Carabus	Predator	Adult			P
Coleoptera		Carabidae	*Cychrus*	*tuberculatus*	Cychrus	Predator	Adult			P
Coleoptera		Carabidae	*Harpalus*	*sp.*	Harpalus	Predator	Adult			P
Coleoptera		Carabidae	*Metrius*	*sp.*	Metrius	Predator	Adult			P
Coleoptera		Carabidae	*Notiophilus*	*sp.*	Notiophilus	Predator	Adult		3800	PLS

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Coleoptera		Carabidae	*Promecognathus*	*sp. 2*	Promecognathus Tiny	Predator	Adult	Tiny		P
Coleoptera		Carabidae	*Pterostichus*	*algidus*	Pterostichus algidus	Predator	Adult			P
Coleoptera		Carabidae	*Pterostichus*	*crenicollis*	Pterostichus crenicollis	Predator	Adult			P
Coleoptera		Carabidae	*Pterostichus*	*herculaneus*	Pterostichus herculaneus	Predator	Adult			P
Coleoptera		Carabidae	*Pterostichus*	*inopinus*	Pterostichus inopinus	Predator	Adult			P
Coleoptera		Carabidae	*Pterostichus*	*lama*	Pterostichus lama	Predator	Adult			P
Coleoptera		Carabidae	*Pterostichus*	*sp.*	Pterostichus	Predator	Adult			P(A,I)L
Coleoptera		Carabidae	*Pterostichus*	*sp. 1*	Pterostichus A	Predator	Adult	sp. A		P
Coleoptera		Carabidae	*Pterostichus*	*sp. 2*	Pterostichus big	Predator	Adult	Big		P
Coleoptera		Carabidae	*Pterostichus*	*sp. 3*	Pterostichus tiny	Predator	Adult	Tiny		P
Coleoptera		Carabidae	*Pterostichus*	*tuberculofusciata*	Pterostichus tuberculofusciata	Predator	Adult			P
Coleoptera		Carabidae	*Scaphinotus*	*angulatus*	Scaphanotis angustatus	Predator	Adult			P
Coleoptera		Carabidae	*Scaphinotus*	*angusticollis*	Scaphanotis angusticollis	Predator	Adult			P
Coleoptera		Carabidae	*Scaphinotus*	*marginatus*	Scaphanotis marginatus	Predator	Adult			P
Coleoptera		Carabidae	*Scaphinotus*	*sp. 1*	Scaphanotis X	Predator	Adult	X		P
Coleoptera		Carabidae	*Scaphinotus*	*sp. 2*	Scaphanotis X2	Predator	Adult	X2		P
Coleoptera		Carabidae	*Zacotus*	*sp.*	Zacotus	Predator	Adult			P
Coleoptera		Carabidae		*sp. 1*	Carabid	Predator	Immature		4900	PLS
Coleoptera		Carabidae		*sp. 2*	Carabid	Predator		Tiny		L
Coleoptera		**Cerambycidae**			Cerambycid	Detritivore	Adult			P
Coleoptera		**Chrysomelidae**	*Altica*	*sp.*	Altica	Herbivore	Adult			P
Coleoptera		Chrysomelidae	*Chrysolina*	*sp*	Chrysolina	Herbivore	Adult			P
Coleoptera		Chrysomelidae	*Clytrine*	*sp*	Clytrine	Detritivore	Adult			P
Coleoptera		Chrysomelidae	*Syneta*	*sp.*	Syneta	Herbivore	Adult			P
Coleoptera		Chrysomelidae	*Timarcha*	*sp.*	Timarcha	Herbivore	Adult			P
Coleoptera		Chrysomelidae			Chrysomelid	Herbivore	Immature		2300	SL
Coleoptera		**Coccinellidae**			Coccinellid larvae	Predator	Immature			P
Coleoptera		**Cucujidae**			Cucujid	Predator	Adult			PL
Coleoptera		**Curculionidae**	*Cossonsus*	*sp*	Cossonsus	Herbivore	Adult			P

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Coleoptera		Curculionidae	*Geodercodes*	*sp.2*	Geodercodes tiny	Herbivore	Adult	Tiny		P
Coleoptera		Curculionidae	*Lobosoma*	*horridum*	Lobosoma	Herbivore	Adult			PL
Coleoptera		Curculionidae	*Rhyncolus*	*sp.*	Rhyncolus	Herbivore	Adult	Weevil		P
Coleoptera		Curculionidae	*Steremnius*	*carinatus*	Steremnius	Herbivore	Adult			PL
Coleoptera		Curculionidae	*Steremnius*	*sp.*	Steremnius X	Herbivore	Adult	X		P
Coleoptera		Curculionidae			Curculionid	Herbivore	Adult	Grooved		PL
Coleoptera		Curculionidae			Curculionid	Herbivore	Immature		2300	S(I)L(A,I)
Coleoptera		Dermestidae			Dermestid	Detritivore	Immature			L
Coleoptera		Derodontidae	*Derodontus*	*sp.*	Derodontus	Fungivore	Adult			P
Coleoptera		Dytiscidae			Dytiscid	Predator	Adult			P
Coleoptera		Elateridae			Elaterid	Detritivore	Adult		3100	P(A)L(I)S(A,I)
Coleoptera		Elateridae			Elaterid	Herbivore	Immature	2 hook		L
Coleoptera		Elateridae			Elaterid Huge	Detritivore	Adult	Huge		P
Coleoptera		Lampyridae	*Ellychnia*	*sp.*	Ellychnia	Predator	Adult		5000	P(A)L(A,I)S(I)
Coleoptera		Lampyridae	*Photuris*	*sp.*	Photuris	Predator	Adult			P(A,I)
Coleoptera		Lathridiidae	*Enicmus*	*sp.*	Enicmus	Fungivore	Adult			PL
Coleoptera		Lathridiidae			Lathridiid	Fungivore	Adult			P
Coleoptera		Leiodidae	*Agathidium*	*sp.*	Agathidium	Fungivore	Adult	L - Slime mold		PL
Coleoptera		Leiodidae	*Anisotoma*	*sp.*	Anisotoma	Slime Mold		(was Anisocoma)		L
Coleoptera		Leiodidae	*Catopocerus*	*sp*	Catopocerus	Detritivore	Adult		1100	PLS
Coleoptera		Leiodidae	*Leiodes*	*sp. 4*	Leiodes	Fungivore	Adult			P
Coleoptera		Leiodidae	*Leiodes*	*sp.1*	Leiodes Big	Fungivore	Adult			P
Coleoptera		Leiodidae	*Leiodes*	*sp.2*	Leiodes 'A'	Fungivore	Adult	Sp. A		P
Coleoptera		Leiodidae	*Leiodes*	*sp.3*	Leiodes 'B'	Fungivore	Adult	Sp. B		P
Coleoptera		Leiodidae			Agathidium-like	Slime Mold				L
Coleoptera		Leiodidae			Fungal Beetle Chordate	Fungivore	Adult	Fungal Beetle Chordate		P
Coleoptera		Leiodidae			Fungal Beetle imm	Fungivore	Immature			P
Coleoptera		Leiodidae			Fungal Beetle Ischio	Fungivore	Adult	Fungal Beetle Ischio		P
Coleoptera		Leiodidae			Fungal Beetle Serrate Leiodid	Fungivore	Adult	Fungal Beetle Serrate Leiodid		P

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Coleoptera		**Melandryidae**			Melandryid	Detritivore	Adult			P
Coleoptera		**Oedemeridae**	*Ditylus*	*sp.*	Ditylus	Detritivore	Adult			P
Coleoptera		**Phengodidae**	*Zarhipis*	*sp.*	Zarhipis	Predator	Adult			P
Coleoptera		**Pselaphidae**	*Actium*	*sp.*	Actium	Predator			600	SL
Coleoptera		Pselaphidae	*Cupila*	*sp.*	Cupila	Predator			850	SL
Coleoptera		Pselaphidae	*Lucifotychus*		Lucifotychus	Predator				L
Coleoptera		Pselaphidae	*Pselaphid*	*sp. 2*	Pselaphid	Predator		Small	600	SL
Coleoptera		Pselaphidae	*Pselaphid*	*sp. 3*	Pselaphid	Predator		*sp. X*		L
Coleoptera		Pselaphidae	*Pselaphtrichus*		Pselaphtrichus	Predator				L
Coleoptera		Pselaphidae	*Pselaphus*	*sp.*	Pselaphus	Predator			1200	SL
Coleoptera		Pselaphidae	*Sonoma*	*sp.*	Sonoma	Predator			850	SL
Coleoptera		Pselaphidae		*sp. 1*	Pselaphid	Predator		Large	1200	PLS
Coleoptera		**Ptiliidae**		*sp. 1*	Ptilid black	Fungivore	Adult	Black	810	PLS
Coleoptera		Ptiliidae		*sp. 2*	Ptilid brown	Fungivore	Adult	Brown		PL
Coleoptera		Ptiliidae		*sp. 3*	Ptilid Y	Fungivore	Adult	Y		P
Coleoptera		**Rhysodidae**	*Rhysodes*	*sp.*	Rhysodes	Predator	Adult			P
Coleoptera		**Salpingidae**	*Pytho*	*sp.*	Pytho	Predator	Adult			P
Coleoptera		**Scarabaeidae**	*Aphodius*	*sp.1*	Aphodius	Detritivore	Adult			P
Coleoptera		Scarabaeidae	*Aphodius*	*sp.2*	Aphodius Tiny	Detritivore	Adult	Tiny		P
Coleoptera		Scarabaeidae	*Bolboceras*	*sp.*	Bolboceras	Detritivore	Adult			P
Coleoptera		Scarabaeidae	*Dichelonyx*	*sp.*	Dichelonyx	Herbivore	Adult			P
Coleoptera		Scarabaeidae			Scarabeid	Herbivore	Immature		3100	PLS
Coleoptera		**Scolytidae**			Scolytid	Detritivore	Adult			P
Coleoptera		**Scydmaenidae**	*Lophioderus*	*sp.*	Lophioderus	Predator	Adult	Large (Wide)		PL
Coleoptera		Scydmaenidae	*Scydmaenus*	*sp.*	Scydmaenus	Predator	Adult		800	PS
Coleoptera		Scydmaenidae	*Veraphis*	*sp.*	Veraphis	Predator	Adult	Small (Narrow)		PL
Coleoptera		**Silphidae**	*Neocrophilus*	*hydrophiles*	Neocrophilus hydrophiles	Necrivore	Adult			P
Coleoptera		Silphidae	*Nicrophorus*	*sp.1*	Nicrophorus	Necrivore	Adult			P
Coleoptera		Silphidae	*Nicrophorus*	*sp.2*	Nicrophorus small	Necrivore	Adult	Small		P

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Coleoptera		Staphylinidae	*Micropeplus*	*sp.*	Micropeplus	Predator	Adult		2400	PLS
Coleoptera		Staphylinidae	*Omaline*	*sp.*	Omalinae	Predator	Adult			PL
Coleoptera		Staphylinidae	*Staphylinus*	*sp.*	Staphylinus	Predator	Adult			P
Coleoptera		Staphylinidae	*Stenus*		Stenus	Predator				L
Coleoptera		Staphylinidae	*Tachinus*	*sp.*	Tachinus	Predator	Adult		3100	PLS
Coleoptera		Staphylinidae		*sp.1*	Aleocharinae Black	Predator	Adult	Black	1950	PS
Coleoptera		Staphylinidae		*sp.2*	Aleocharinae Brown	Predator	Adult	Brown	1900	PLS
Coleoptera		Staphylinidae		*sp.3*	Aleocharinae sp. C	Predator	Adult	Sp. C	1200	PLS
Coleoptera		Staphylinidae		*sp. 1*	Staphylinid	Predator	Adult		4500	PLS
Coleoptera		Staphylinidae		*sp. 2*	Staphylinid	Predator	Adult	Large	10000	SL
Coleoptera		Tenebrionidae	*Coelocnemis*	*sp. 1*	Coelocnemus	Detritivore	Adult			P
Coleoptera		Tenebrionidae	*Coelocnemis*	*sp. 2*	Coelocnemus-like black	Detritivore	Adult			P
Coleoptera		Tenebrionidae	*Eleodes*	*sp. 1*	Eleodes Narrow	Detritivore	Adult	Narrow, (was sp. 3)		P
Coleoptera		Tenebrionidae	*Eleodes*	*sp. 2*	Eleodes Wide	Detritivore	Adult	Wide, (was sp. 5)		P
Coleoptera		Tenebrionidae	*Microtribolium*	*sp.*	Microtribolium	Herbivore	Adult			P
Coleoptera		Tenebrionidae	*Tribolium*	*sp. 1*	Tribolium Large	Detritivore	Adult	Large		P
Coleoptera		Tenebrionidae	*Tribolium*	*sp. 2*	Tribolium Small	Detritivore	Adult	Small		P
Coleoptera		Tenebrionidae			Tenebrionid	Detritivore	Adult		2800	P(A)L(I)S(I)
Coleoptera		Throscidae			Throscid	Predator	Adult			P
Coleoptera		Zopheridae	*Phellopsis*	*sp.*	Phellopsis	Fungivore	Adult			P
Coleoptera		Zopheridae	*Usechomorpha*	*sp.*	Usechomorpha	Fungivore	Adult	(L-Tenebrionid)		PL
Collembola		Entomobryidae	*Entomobrya*	*sp. 1*	Entomobrya	Fungivore		Striped	30	SL
Collembola		Entomobryidae	*Entomobrya*	*triangularis*	Entomobrya	Fungivore			27	SL
Collembola		Entomobryidae	*Sinella*	*sp.*	Sinella	Fungivore				SL
Collembola		Entomobryidae	*Tomocerus*	*sp.*	Tomocerus	Fungivore			55	SL
Collembola		Hypogastruridae	*Hypogastrura*	*sp.*	Hypogastrura	Fungivore			20	SL
Collembola		Hypogastruridae	*Neanura*	*sp*	Neanura	Predator			285	SL
Collembola		Hypogastruridae	*Pseudachorutes*	*sp.*	Pseudachorutes	Fungivore			22	SL
Collembola		Isotomidae	*Folsomia*	*sp.*	Folsomia	Fungivore			8	SL

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Collembola		**Neelidae**	*Neelus*	*sp.*	Neelus	Fungivore				L
Collembola		**Onychiuridae**	*Onychiurus*	*sp. 1*	Onychiurus	Fungivore		Large	70	SL
Collembola		Onychiuridae	*Onychiurus*	*sp. 2*	Onychiurus	Fungivore		Small	12	SL
Collembola		**Sminthuridae**	*Ptenothrix*	*sp.*	Ptenothrix	Fungivore				L
Collembola		Sminthuridae	*Sminthurus*	*sp.*	Sminthurus	Fungivore			8	SL
Dermaptera		**Forficulidae**	*Forficula*	*auricularia*	Forficula auricularia	Omnivore	Adult			P
Diplopoda		**Caseyidae**	*Caseya*	*sp.1*	Caseya	Detritivore	Adult		4500	P(A)L(A,I)S(?)
Diplopoda		Caseyidae	*Caseya*	*sp.2*	Caseya long & thin	Detritivore	Adult	long & thin		P
Diplopoda		Caseyidae	*Caseya*	*sp.3*	Caseya tiny	Detritivore	Adult	Tiny		P
Diplopoda		Caseyidae	*Veshingtonia*	*sp.*	Julid	Detritivore	Adult			P(A)L(I)
Diplopoda		**Conotylidae**	*Talyutyla*	*sp.*	Caseya w/hook	Detritivore	Adult	w/ hook		P
Diplopoda		**Nearctodesmidae**	*Nearctodesmus*	*sp.*	Nearctodesmus	Detritivore	Adult		20000	P(A)L(I)S(I)
Diplopoda		**Parajulidae**	*Bollmanella*	*sp.*	Bollmanella	Detritivore	Adult		5700	PLS
Diplopoda		**Polydesmidae**	*Scytonotus*	*sp.*	Scytonotus	Detritivore	Adult		18000	PLS
Diplopoda		Polyxenidae	*Polyxenes*	*sp.*	Polyxenes	Lichenivore	Adult		4000	PLS
Diplopoda		**Polyzoniidae**	*Bdellozonium*	*sp.*	Bdellozonium	Unknown	Adult			P(A)L(A,I)
Diplopoda		**Spirobolidae**	*Tylobolus*	*sp. 1*	Tylobolus	Detritivore	Adult			P
Diplopoda		Spirobolidae	*Tylobolus*	*sp. 2*	Tylobolus B	Detritivore	Adult			P
Diplopoda		**Striariidae**	*Amplaria*	*sp.*	Lysiopet	Detritivore	Adult			P
Diplopoda		Striariidae	*Amplaria*	*sp1*	Conotyla	Detritivore	Adult			P
Diplopoda		Striariidae	*Amplaria*	*sp2*	Conotyla tiny	Detritivore	Adult			P
Diplopoda		**Xystodesmidae**	*Harpaphe*	*haydenii*	Harpaphe	Detritivore	Adult		25000	P(A)L(A,I)S(I)
Diplopoda			*Chordeuma*		Chordeuma	Detritivore				L
Diplopoda			*Lysiopetala*		Lysiopetala	Detritivore				L
Diplura		**Campodeidae**			Campodeidae	Fungivore	Adult		1950	PLS
Diplura		**Japygidae**	*Japyx*	*sp*	Japyx	Predator	Adult		2500	SL
Diptera		**Anthomyiidae**			Anthomyiid	Herbivore	Adult			L
Diptera		**Asilidae**			Asilid	Predator	Immature		1100	PLS
Diptera		**Bibionidae**			Bibionid	Herbivore	Immature		2200	SL

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Diptera		**Chironomidae**			Chironomid	Fungivore	Immature	Adult: Non-feeder	1800	S(I)L(A,I)
Diptera		**Muscidae**	*Fannia*	*sp.*	Fannia	Herbivore				L
Diptera		**Mycetophilidae**			Mycetophilid gnat	Fungivore	Adult	gnat		P
Diptera		**Psychodidae**			Psychodidae	Fungivore			1100	P(A)L(A,I)S(I)
Diptera		**Sciaridae**			Sciarid	Fungivore	Adult	Imm - Detritivore	3900	S(A)L(A,I)
Diptera		**Sphaeroceridae**			Sphaerocerid	Fungivore	Adult			L
Diptera		**Syrphidae**			Syrphid imm	Predator	Immature			P
Diptera		**Tipulidae**	*Chionea*	*sp*	Chionea	Detritivore	Adult			P
Diptera		Tipulidae			Tipulid	Detritivore			4500	P(A)L(A,I)S(I)
Hemiptera		**Aradidae**	*Aradus*	*sp.*	Aradus	Fungivore	Adult			P
Hemiptera		Aradidae			Aradid	Fungivore	Adult			P
Hemiptera		**Berytidae**			Berytid	Herbivore	Adult			P
Hemiptera		**Cydnidae**			Cydnid	Detritivore	Adult			P
Hemiptera		**Largidae**			Largid	Herbivore	Adult			P
Hemiptera		**Lygaeidae**			Lygaeid	Herbivore	Adult		1900	P(A)L(I)S(I)
Hemiptera		**Miridae**	*Dicyphus*	*sp.*	Dicyphus	Predator	Adult			P
Hemiptera		Miridae			Miridae	Herbivore	Adult			P
Hemiptera		**Nabidae**	*Nabis*	*sp.*	Nabis	Predator	Adult			P
Hemiptera		**Reduviidae**			Mantid	Predator	Adult			P
Hemiptera		Reduviidae			Reduvild	Predator	Adult			P
Hemiptera		**Rhopalidae**	*Boisea*	*trivittatus*	Box Elder	Herbivore	Adult			P
Hemiptera		**Tingidae**	*Acalypta*	*sp.*	Acalypta	Herbivore	Adult		810	P(A)L(I)S(I)
Hemiptera					Hemiptera X	Predator	Adult	Hemiptera X		P
Homoptera		**Aphidae**			Aphid	Herbivore	Adult			P
Homoptera		**Cicadellidae**			Homoptera	Herbivore	Adult			PL
Homoptera		**Cicadidae**	*Cicada*	*sp*	Cicada	Herbivore	Adult			P
Homoptera		**Orthezilidae**	*Orthezia*	*californica*	Orthezia	Herbivore	Adult		1800	PLS
Homoptera		**Pseudococcidae**			Mealy bug	Herbivore				L
Hymenoptera		**Bethylidae**			Forceps wasp	Parasite	Adult			P

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Hymenoptera		**Diapriidae**		*sp.1*	Diapriid 'A'	Parasite	Adult	Sp. A		P
Hymenoptera		Diapriidae		*sp.2*	Diapriid 'B'	Parasite	Adult	Sp. B		P
Hymenoptera		Diapriidae		*sp. 3*	Diapriid	Parasite	Adult		950	PLS
Hymenoptera		**Dryinidae**		*sp.*	Dryinid	Parasite	Adult			L
Hymenoptera		**Formicidae**	*Aphaenogaster*	*sp.1*	Aphaenogaster Huge	Predator	Adult	Huge		P
Hymenoptera		Formicidae	*Aphaenogaster*	*sp.2*	Aphaenogaster Large	Predator	Adult	Large		PL
Hymenoptera		Formicidae	*Aphaenogaster*	*sp.3*	Aphaenogaster Small	Predator	Adult	Small	2100	PLS
Hymenoptera		Formicidae	*Camponotis*	*laevigatus*	Camponotus laevigatus	Omnivore	Adult			P
Hymneoptera		Formicidae	*Camponotis*	*modoc*	Camponotus modoc	Omnivore	Adult	Black		P
Hymenoptera		Formicidae	*Camponotis*	*noveboracensus*	Camponotus novaboracensus	Omnivore	Adult	Red / Black		P
Hymenoptera		Formicidae	*Formica*	*fusca*	Formica fusca	Omnivore	Adult			P
Hymenoptera		Formicidae	*Formica*	*pacifica*	Formica pacifica	Omnivore	Adult			P
Hymenoptera		Formicidae	*Formica*	*rufa*	Formica rufa	Omnivore	Adult			P
Hymenoptera		Formicidae	*Formica*	*sanguinea*	Formica sanguinea	Omnivore	Adult			P
Hymenoptera		Formicidae	*Lasius*	*sp. 1*	Lasius Small	Omnivore	Adult	Small	1400	PLS
Hymenoptera		Formicidae	*Lasius*	*sp. 2*	Lasius Large	Omnivore	Adult	Large		P
Hymenoptera		Formicidae	*Solenopsis*	*sp.*	Solenopsis	Predator	Adult			P
Hymenoptera		Formicidae	*Tapinoma*	*sp.*	Tapinoma	Omnivore	Adult		1600	PLS
Hymenoptera		**Ichneumonidae**	*Gelis*	*sp.*	Gelis	Predator	Adult		2000	SL
Hymenoptera		Ichneumonidae		*sp. 1*	Parasitic wasp	Parasite		Tiny		L
Hymenoptera		Ichneumonidae			Ichneumon wasp	Parasite	Adult			PL
Hymenoptera		**Platygarteridae**			Platygasteridae	Parasite	Adult			PL
Hymenoptera		**Pompilidae**			Pompilid	Predator	Adult			P
Hymenoptera		**Tenthredinidae**			Sawfly	Herbivore	Adult			P(A)L(I)
Hymenoptera		Tenthredinidae			Tenthredinid	Herbivore	Adult			P
Hymenoptera		**Vespidae**	*Vespa*	*sp.*	Vespa	Predator	Adult			P
Isopoda		**Ligidiidae**	*Ligidium*	*gracile*	Ligidium	Detritivore	Adult			PL
Isopoda		Ligidiidae	*Ligidium*	*sp.1*	Ligidium Large	Detritivore	Adult	Large		P
Isopoda			*Armadillidium*	*sp.*	Armadillidium	Detritivore	Adult			P

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Species List con't.

Order	Sub-order	Family	Genus	Species	ID	Trophic level	Life stage	Description	Biomass	Method *
Lepidoptera		Geometridae			Geometer catepillar	Herbivore	Immature			P
Lepidoptera		Lymantriidae	*Malacosoma*	*sp.*	Lymantriid	Herbivore	Adult			P
Lepidoptera		Noctuidae			Noctuid catepillar	Herbivore	Immature			PS
Lepidoptera					Microlepidotera	Herbivore				L
Mecoptera		Panorpidae			Brachypanorpa	Predator	Adult			P
Microcoryphia		Meinterellidae	*Meinterella*	*sp.*	Machilid	Lichenivore	Adult			PL
Mollusca		Limacidae	*Ariolimax*	*sp.*	Ariolimax	Herbivore	Adult			P
Mollusca			*Haplotrema*	*sp.*	Haplotrema	Predator	Adult			PL
Mollusca			*Monadenia*	*sp.*	Monadenia	Predator	Adult			P
Mollusca			*Pupilla*	*sp.*	Pupilla	Herbivore			3000	SL
Mollusca			*Vespericola*	*sp.*	Vespericola	Herbivore	Adult			P
Mollusca					Slug	Herbivore				L
Neuroptera		Chrysopidae			Chrysopid	Predator	Adult			P
Neuroptera		Hemerobiidae			Hemorobiid	Predator	Adult			P
Neuroptera		Raphidiidae	*Agulla*	*sp.*	Agulla	Predator	Adult		14900	P(A)L(I)S(?)
Opiliones		Ischyropsalididae	*Hesperonemastoma*		Hesperonemastoma	Predator	Adult			PL
Opiliones		Ischyropsalididae	*Sabacon*	*sp.*	Sabacon	Predator	Adult			PL
Opiliones		Ischyropsalididae	*Taracus*	*sp.*	Taracus	Predator	Adult			P(A)L(A,I)
Opiliones		Nemastomatidae	*Ceratolasma*	*sp*	Ceratolasma	Predator	Adult			P
Opiliones		Nemastomatidae	*Dendrolasma*	*sp.*	Dendrolasma	Predator	Adult			PL
Opiliones		Phalangiidae	*Lelobunum*	*sp.*	Phalangium Big	Predator	Adult			P
Opiliones		Phalangiidae	*Leuronychus*	*sp.*	Leuronychus	Predator	Adult			PL
Opiliones		Phalangiidae	*Phalangium*	*sp.*	Phalangium	Predator	Adult			P
Opiliones		Sironidae	*Siro*	*acaroides*	Sciro	Predator	Adult			P
Opiliones		Triaenonychidae	*Metanonychus*	*sp.*	Metanonychus	Predator			6500	P(A)L(I)S
Opiliones		Triaenonychidae	*Sclerobunus*	*sp.*	Sclerobunus	Predator	Adult	Big Red		P
Opiliones			*Siro*	*sp.*	Siro	Predator			5500	SL
Orthoptera		Gryllacrididae	*Pristoceuthophilus*	*sp.*	Pristoceuthophilus	Unknown	Adult			P(A,I)
Orthoptera		Gryllidae	*Oecantha*	*sp.*	Oecantha	Herbivore	Adult			P

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Species List con't.

Order	Sub-order	Family	Genus	Species	ID	Trophic level	Life stage	Description	Biomass	Method *
Pauropoda					Eupauropod	Fungivore			45	SL
Protura					Protura	Fungivore			500	SL
Pseudoscorpiones	**Chelonethida**	**Chthoniidae**	*Apochthonius*	*sp.*	Apochthonius	Predator	Adult		1900	P(A)L(A,I)S(A)
Pseudoscorpiones	Chelonethida	Chthoniidae	*Pseudotyrannochthonius*	*sp.*	Pseudotyrannochthonius	Predator	Adult			PL
Pseudoscorpiones	Chelonethida	**Neobisiidae**	*Microcreagus*	*sp.*	Microcreagus	Predator	Adult		2300	PLS
Pseudoscorpiones			*Garypus*	*sp.*	Garypus	Predator				L
Psocoptera		**Liposcelidae**	*Liposcelis*	*sp.*	Liposcelis	Lichenivore	Adult		375	PLS
Psocoptera					Psocoptera	Lichenivore	Adult		1100	PLS
Scorpionida		**Vejovidae**	*Oroctonos*	*mordax*	Uroctenes	Predator	Adult			P
Siphonaptera					Siphonaptera	Parasite	Adult			P
Symphyta			*Scutigerella*	*sp.*	Scutigerella	Herbivore			2490	SL
Thysanoptera					Thrips	Fungivore			670	SL

***Key**

P = Pitfall

L = Litter

S = Soil

A = Adult

I = Immature